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Validity and Design of Environmental Surveillance Systems for Operating Nuclear Power Plants

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ABSTRACT

The composition and procedures of environmental surveillance programs at completed and operating nuclear power plants have been examined with respect to their validity, continuing significance and cost. It was found that many programs contain components that are mainly an extension of pre-operational baseline measurements that need not be continued indefinitely and that others lack the statistical validity to make their continued application meaningful.

To identify the practical limits imposed by counting statistics and realistic equipment capacity measurements were done on iodine-131 and cesium-137 containing samples to establish detectability limits and proportionate costs for sample preparation and counting. It was found that under commercial conditions effective detectability limits and expected confidence limits were substantially higher than those mentioned in NRC Regulatory Guides. This imposes a need for either selecting fewer samples and counting them for longer times or accepting a lesser accuracy on more samples, within the bounds of reasonable cost per sample.

In planning programs to extend over the routine operation of the plant over a 30-40 year period, selection criteria are proposed to select only those samples and analyses that are of sufficient continuing importance to justify their indefinite retention. Other program elements of local importance may be added, subject also to a flexible response whenever radioactive release levels from the plant rise for any reason.

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SUMMARY

Environmental surveillance programs constitute the one continuing aspect of any determination of the environmental impact of nuclear power plants. They typically are made up of a series of biological observations, including observations on species, populations, temperature effects and crop variations, and radiological measurements, consisting of analyses of radioactive contaminants in water, airborne particulates, food animals, soils and vegetation. The cost and complexity of such programs has grown immensely over the years and the purpose of the present project was to assess the usefulness and effectiveness of the various program components, to determine the extent to which some of them are directed mainly at meeting regulatory requirements or external image-building purposes, and to recommend criteria for directing future trends in the conduct and organization of surveillance programs.

The project consisted of three phases: 1. A wide range of operating or near-operating nuclear power plants were visited to observe surveillance activities and to view related facilities. Discussions were held with responsible plant personnel and with senior persons engaged in commercial analyses of environmental samples. From these discussions a composite picture has emerged regarding the customary methods of sampling and analysis and the ultimate usefulness plant personnel themselves assign to some of these activities. The effect of in-house or contractual performance of assay work was also discussed. 2. To obtain an independent evaluation of the work involved and the accuracy obtainable by "standard" analytical procedures, representative counting equipment was set up for determinations of iodine-131, strontium-90 and cesium-137. Radiochemical extractions and careful radiometric analyses were performed to provide information on man-hour requirements, costs of analysis and on statistical and non-statistical sources of error. 3. Criteria were developed to evaluate the effectiveness of various survey components. Within existing regulatory requirements, it was found that a trade-off may develop between desired detection levels, attainable accuracy and sample number if one accepts the existence of certain

economic limitations on any surveillance program forming part of a commercial power-generating facility.

A series of recommendations has been formulated regarding the use of action-level phasing of surveillance programs, the elimination of manifestly cost-ineffective program components, such as entrainment loss analyses or certain types of soil sampling. The use of critical path analysis is supported as a means of eliminating less necessary operations and the relative advantages of contractor-operated or company-operated laboratory facilities are discussed.

Section 1

INTRODUCTION

The construction and operation of nuclear power plants inevitably involve considerable costs and some environmental impact. To a certain extent the environmental effects are similar to those due to any industrial activity of comparable size and complexity, and can be readily anticipated and accounted for. Certain forms of environmental impact, such as the magnitude of waste heat dissipation and fuel and waste transportation activities are related to the nature and scale of power generation of any type; however others, notably those associated with the release of low-level radioactive effluents to air and water, are peculiar to nuclear power plants and have received particular attention owing to the atmosphere of controversy that has surrounded nuclear facilities in recent years.

Under the National Environmental Policy Act (NEPA) of 1969 and subsequent regulations of the U.S. Atomic Energy Commission and Nuclear Regulatory Commission, any prospective operator of a nuclear power plant must submit a detailed environmental statement when applying for a construction and operating license. That statement must contain a description of the proposed plant and the plant site, an evaluation of alternative sites and plant systems with respect to relative costs and environmental effects, and a general assessment of potential effects during construction and operation of the plant on the existing flora and fauna, and of radiation effects in terms of the predicted radiation dose commitment to any surrounding population.

To enable an applicant to submit environmental data of adequate reliability and detail, it is usually necessary to search local records for historical accounts of weather phenomena, floods, earthquakes and ground disturbances, and to conduct surveys on the existing ecological conditions, meteorological phenomena, air and water quality fluctuations, and land use and productivity for a period of at least one or two years preceding the final site selection. Such surveys provide baseline data for projecting impact effects with and without plant operations for the expected useful lifetime of the plant and serve to indicate any critical population groups or pathways within the ecosystem or the human population in the affected region. The ecological surveys typically include a census of vegetation types, community types and important species of terrestrial and amphibious vertebrates and birds, the identification of any rare or endangered species found regularly or occasionally in the study area, and at some places an identification of algal types and insect populations. Since most power plants are located on bodies of fresh water or sea water, types and population data are also obtained on fish, mollusks, crustacea and benthic organisms as appropriate, with emphasis on commercially valuable species or those of importance to sports fishermen.

Radiological surveys are intended to indicate existing occurrences and anomalies in the radioactive background from terrestrial sources of uranium and thorium in minerals that may give rise to measurable radioactivity in streams and well water or to high radon and radon-daughter concentrations in the atmosphere. They would indicate fallout activities and, perhaps, correlate them with national observations on their rise and decay, and would identify the existence of potential radioactive contamination from any other nuclear or non-nuclear facility.

In general this entails a very extensive pre-operational survey of air, water, vegetation, soil and milk samples taken around the prospective site at frequent intervals, and expenditures ranging typically from $100,000 to $300,000 over a one to three-year period. Some of this expense goes to environmental consultants, biological research institutes and university departments, and utilities have been encouraged, as a gesture of good will, to expand some of the early survey programs into environmental research projects of more general, regional applicability. In most states such surveillance programs are not eligible for consideration in rate-fixing arguments and are usually considered an administrative overhead.

Once a power plant becomes operational, the second survey phase, the environmental surveillance program, becomes effective, and it is this phase that the present project is principally concerned with. The main objectives of the environmental surveillance program are to verify the performance estimates for effluent emission and dispersion, and to warn of any unexpected or accidental effects due to plant operations or effluents. In addition, a well-conducted surveillance program serves to provide dose and population exposure data for possible legal actions, to allay public alarm and to keep the public informed, and to form the basis of any planned emergency program.

The surveillance program is usually designed by a qualified consultant early in the formulation stage of the environmental statement and its details tend to be embedded in the plant's Technical Specifications, and as such are part of the license process. Ideally the program incorporates experience obtained at other operating plants; in practice, there appears to have been a steady process of accretion as more and more additional samples and analyses have been included, and only rarely has any item been removed from the programs. Consequently, the cost in manpower and equipment has become a small, but finite portion of the annual operating cost of the power station, fuel costs excepted, and it seems appropriate and timely to conduct a critical examination of the surveillance operations (1,2,3,4,5).

For this purpose, the present project has been divided into three parts:

A. An inspection and general review of biological and radiological surveillance programs at a representative number of inland power plants

B. An evaluation of laboratory procedures for the analysis of iodine, strontium and cesium in environmental samples, for the purpose of establishing state-of-the-art capabilities and the cost factors associated with various requirements as to analytical precision, sample size and laboratory capacity

C. An examination of the cost factors involved in various samples and analyses, and the trade-off encountered when a surveillance program is expanded or the analytical requirements are tightened. In this phase, also, some considerations regarding cost and efficiency of in-house versus contractor analytical operations have been attempted and the potential of survey programs for adding or including off-site emergency operations has been reviewed.

The work done in each category will be presented in the following sections. An approach to derive criteria from them by which the utility and effectiveness of a surveillance program can be judged, will be presented bearing in mind the substantial differences in local geographical and ecological situations that exist.

Section 2

SURVEY OF SURVEILLANCE PROGRAMS

GENERAL REMARKS

Environmental surveillance programs may be divided into biological and radiological programs, but this division usually relates more to the type of sample evaluation than to the nature of the sample. At some plants aquatic samples or vegetation samples may be collected by one group and part of the samples split off for analysis by the other. In other locations separate contractors collect and analyze samples to determine radioactivity levels or ecological changes, and the program cost is mainly related to sampling effort rather than to laboratory analyses. For this reason some attempt will be made in this chapter to record organizational and contractual arrangements as well as the composition of surveillance programs themselves. Although the main emphasis in this evaluation has been placed on radiological programs, it will be seen that it is usually appropriate to take an overview over the whole environmental surveillance program.

For the present purpose the "environmental" program will be taken to represent all activities monitoring any real or potential effects arising from the plant's existence or operation beyond the fence line. This represents a convenient and practical division since any monitoring work done on site "inside the fence" falls under the responsibility of the plant manager and is usually conducted by the plant's Health Physics personnel, whereas off-site sampling and measurements may be conducted by contractual arrangement and usually depend on the goodwill and cooperation of the surrounding population.

There are also differences in the orders of magnitude of the effects observed. On site, some ecological effects are usually unavoidable and clearly related to construction activities and plant operations, and hence closely in accordance with predicted effects. Radioactivity measurements include determinations of stack releases and liquid effluents and are part of normal plant monitoring activities and subject to continuous record keeping.

Off site, the situation is quite different. Radioactivity levels in air, water, milk, etc., are usually due mostly to natural radiation background and weapons fallout, and any predicted plant-related added activity from liquid or airborne effluents would be expected to be so low as to be very difficult to distinguish in comparison. Furthermore, as distance from the plant increases, fluctuations in radioactivity or ecological effects that may be observed become increasingly more difficult to connect unambiguously to plant operations, except perhaps following a major incident leading to significant releases of radionuclides. For this reason it is important to remember the purposes of the surveillance program and to ensure that samples analyzed do have some practical significance both when they show a positive or a negative indication.

Surveillance programs are usually divided into three categories:

a. Pre-operational programs
b. Operational programs
c. Post-operational programs

Post-operational programs typically relate to decommissioning of a facility and site restoration and are beyond the scope of these discussions. The pre-operational program provides the baseline information for the draft and final environmental statements and, at this time, tends to be fairly extensive, exhaustive and expensive. It should permit identification of local environmental parameters that are significant and deserve continued observation, and should pinpoint meteorological and hydrological conditions that would dictate the sampling locations and sample frequency of subsequent surveillance activities and ensure that these activities result in meaningful observations.

In practice, particularly with delays in plant completion, the pre-operational phase may cover a period of 3-6 years and entail substantial expenditures. There is often a tendency to maintain its full scope into the operational period, largely because of the phrasing of the Technical Specifications. Figure 1 illustrates the complexity and time scale of such ecological programs for one plant; several of the programs go on for 4-5 years and may continue further.

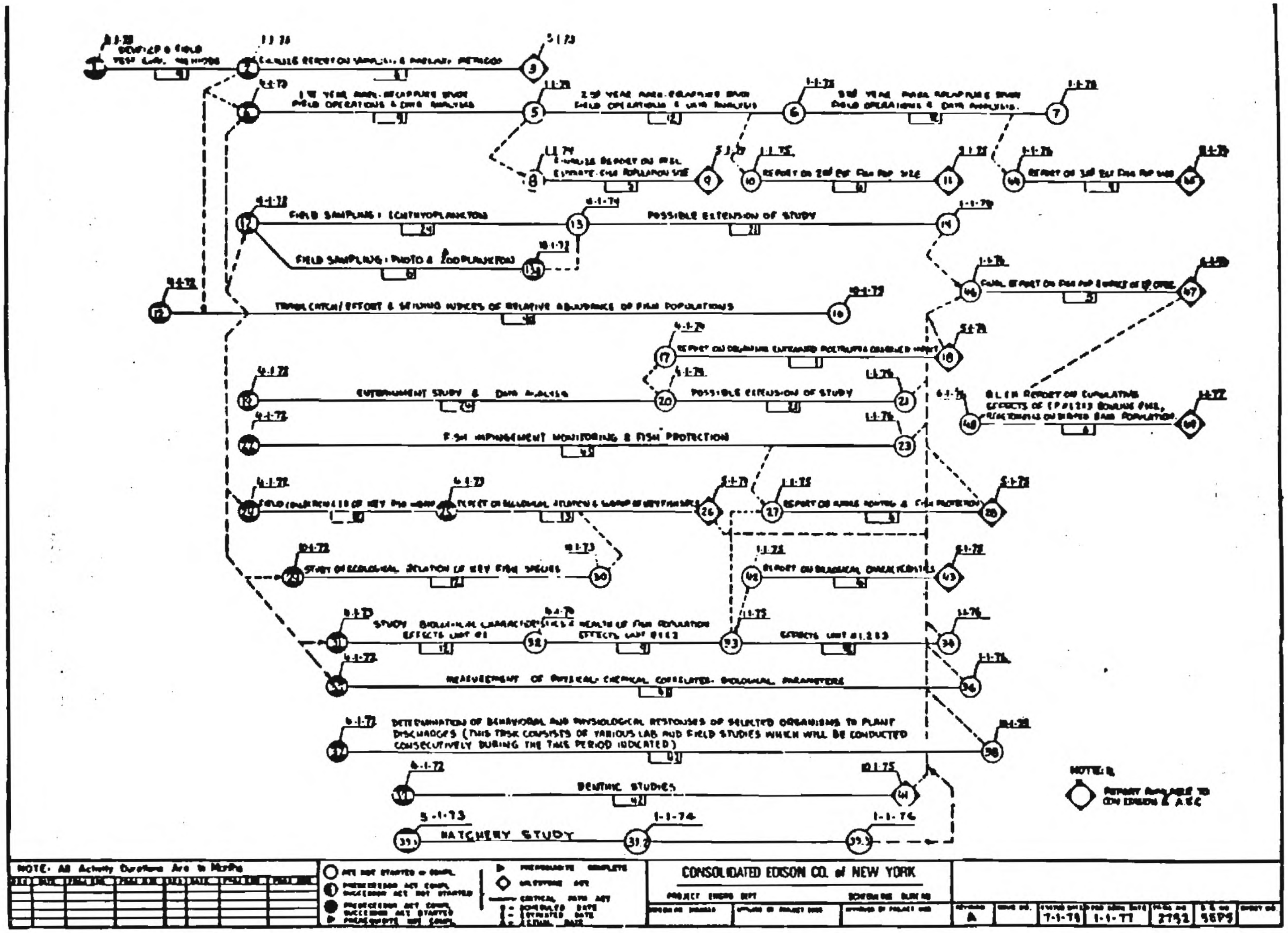

Figure 2-1. General Ecological Survey and Special Studies

Based on the data collected prior to plant start-up, the operational-phase program should be directed towards verification of estimated effects, whether positive or negative, of actual plant operation and should be confined to activities that are sensitive to any changes in such effects or that can be directly related to any potential radiation or environmental effects on the ecology or human population in the vicinity of the plant.

The objectives of the operational phase of the surveillance program thus are substantially different from the pre-operational phase and may be summarized as follows. They should

- provide an early warning of the appearance or accumulation of any radioactive material in the environment, caused by operation of the plant
- provide an estimate of actual risk and exposure, and of cumulative dose, to the surrounding population
- meet requirements of regulatory agencies
- evaluate and back up the adequacy and proper functioning of plant effluent controls and plant monitoring systems
- provide assurance to the public that the plant's environmental impact is known and within anticipated limits
- provide standby monitoring capability for rapid assessment of risk in the event of unanticipated or accidental releases of radioactive material beyond the fenceline
- supply additional data for future construction of nuclear or other facilities in that locality

Note that we have not included any reference to research activities or increased scientific understanding of environmental phenomena among the above objectives; although such research is undoubtedly desirable, it may be arguable if that should be a principal objective of routine monitoring activities by the operator of a power-generating facility.

To obtain some information on the extent to which these objectives are currently being met at various nuclear power plants, a number of companies were visited and their surveillance programs were discussed with the responsible staff members. The procedure and conclusions of these discussions are summarized in the following sections.

Before discussing the surveillance programs in detail, two other factors must be pointed out. Firstly, the activities found in environmental samples are expected to be, and hopefully found to be, very low and near the limit of detectability. Consequently, what activity is detected almost invariably is dominated by weapons fallout and natural radioactivity making it difficult to detect any relatively small increments that may arise from plant operations. It, therefore, becomes important to correlate sample activities with those in similar samples beyond the range of plant effluents, and this is done by the use of "matched samples" from near and distant locations and through national data collected on fallout activities, such as the Milk Network and HASL and EPA reports. In practice, though, unless plant-related activities become comparable to fallout levels, they are liable to remain undetected. For this reason, as a rule, greater credence is given to effluent monitor measurements at the plant, which would be substantially higher than environmental sample activities and are most directly correlated with plant operations. This tends to result in a downgrading of both the value and validity of many types of environmental samples, especially those collected at some distance from the plant. It also requires a higher degree of confidence in the accuracy and reliability of the effluent monitors than is often justified.

The second point is a growing realization that it is both expensive and demoralizing to collect samples that continually show negative results, i.e. mere background activity, even though that is, of course, the desired state. Consequently, many power plants have provision in their Tech Specs for a gradual reduction in sample number and sample frequencies after specified periods of zero-activity readings. Such a phasing-out of samples usually provides for three stages of surveillance operations from an early intensive sample plan to a low-level stage after long periods of accident-free, uneventful operation. This approach will be encountered below in connection with a few power plants and may set a pattern for most, once reliable operation has been demonstrated and enough data have been collected to reassure the public.

VISITS TO SPECIFIC NUCLEAR POWER PLANTS

Table 2-1 lists the power companies and the plant sites visited in the course of this project. In planning these visits, which were arranged in conjunction with EPRI, an attempt was made to have a representative mix of PWR and BWR plants, with the Fort St. Vrain station to represent HTGR's. To maintain comparability of programs, it was decided to restrict plants under consideration to those at inland sites only, to eliminate added considerations that

Table 2-1

LIST OF PLANTS AND SURVEILLANCE PROGRAMS REVIEWED

Company	Plant	Type	Commercial Operation	Visit to H.Q.	Visit to Plant
Duke Power Company	Oconee	PWR/BW	1973		X
Carolina Power & Light	H B Robinson 2	PWR/W	1971	X	
	Brunswick		1975	X	
Tennessee Valley Authority	Sequoyah	PWR/W	--	X	
	Browns Ferry	BWR	1974	X	X
	Watts Bar	PWR/W	--		
Virginia Electric Power	North Anna	PWR/W	--		X
	Surry	PWR/W	1972	X	
Omaha Public Service	Fort Calhoun	PWR/CE	1973	X	X
Colorado Public Service	Fort St. Vrain	HTGR	--	X	X
Yankee Atomic Power	Vermont Yankee	BWR	1972	X	X
	Yankee Rowe	PWR/W	1960	X	X
	Haddam Neck	PWR/W	1968	X	
	Maine Yankee	PWR/CE	1972	X	
Consolidated Edison	Indian Point	PWR/BW	1962		X
Niagara Mohawk Power	Nine Mile Point	BWR	1969		X
New York State Power Authority	Fitzpatrick	BWR	1975		X
Commonwealth Edison	Zion	PWR/W	1973	X	
	Quad Cities	BWR	1972	X	
Georgia Power	Hatch	BWR	1972		X
Northern States Power	Monticello	BWR	1971	X	X
	Prairie Island	PWR/W	1973	X	
Sacramento Municipal Power	Rancho Seco	PWR/BW	1975		X

PWR NSSS suppliers:

BW - Babcock & Wilcox

W - Westinghouse

CE - Combustion Engineering

arise in a coastal environment; a few shore-site plants were included in discussions with companies that operate plants both at inland and seashore locations. Figure 2-2 indicates plants visited or discussed (circles).

Depending on local arrangements and other commitments of personnel concerned, plant operations in many cases were first reviewed at company headquarters with the person most directly responsible for offsite survey programs and for liaison with any analytical contractor. At that time organizational arrangements and program details were reviewed to highlight any problems or special features. Wherever possible, the persons interviewed were asked to evaluate subjectively what they considered to be the strengths and weaknesses of their programs; such expressions of opinion were treated as confidential, but in the aggregate have been taken into account in formulating some of the conclusions of the present project. In most cases the plant site was then visited and the on-site arrangements for sample collection, sample analysis and, where appropriate, for emergency procedures were discussed with senior health physics personnel and usually inspected. In all cases the health physics staff were very cooperative, helpful and patient. As Table 2-1 shows, a total of 14 electric utilities was visited in the course of this study representing over 20 operating or near-operating nuclear power stations. In most cases copies of the environmental reports for 1974 to the AEC were made available to provide supplementary data.

Because many operators have their environmental analyses performed by contractors, additional meetings were arranged with three radiological service companies (Eberline Instrument Corp., Radiation Measurement & Control, and Teledyne Isotopes Co.) and one biological research group (Thorne Ecological Institute). These contacts, too, proved useful in assessing surveillance programs from the contractors' point of view and their willingness to discuss such assay programs frankly and in detail was greatly appreciated.

RADIOLOGICAL SURVEY PROGRAMS

In reviewing the information obtained one should realize that the year 1975 was a period of rapid change in philosophy and practice in environmental surveillance programs. Many programs in use had been designed years before, when the Environmental Statement was first prepared, when few published guidelines existed other than the ICRP Report of Committee 4 of 1965 (6).

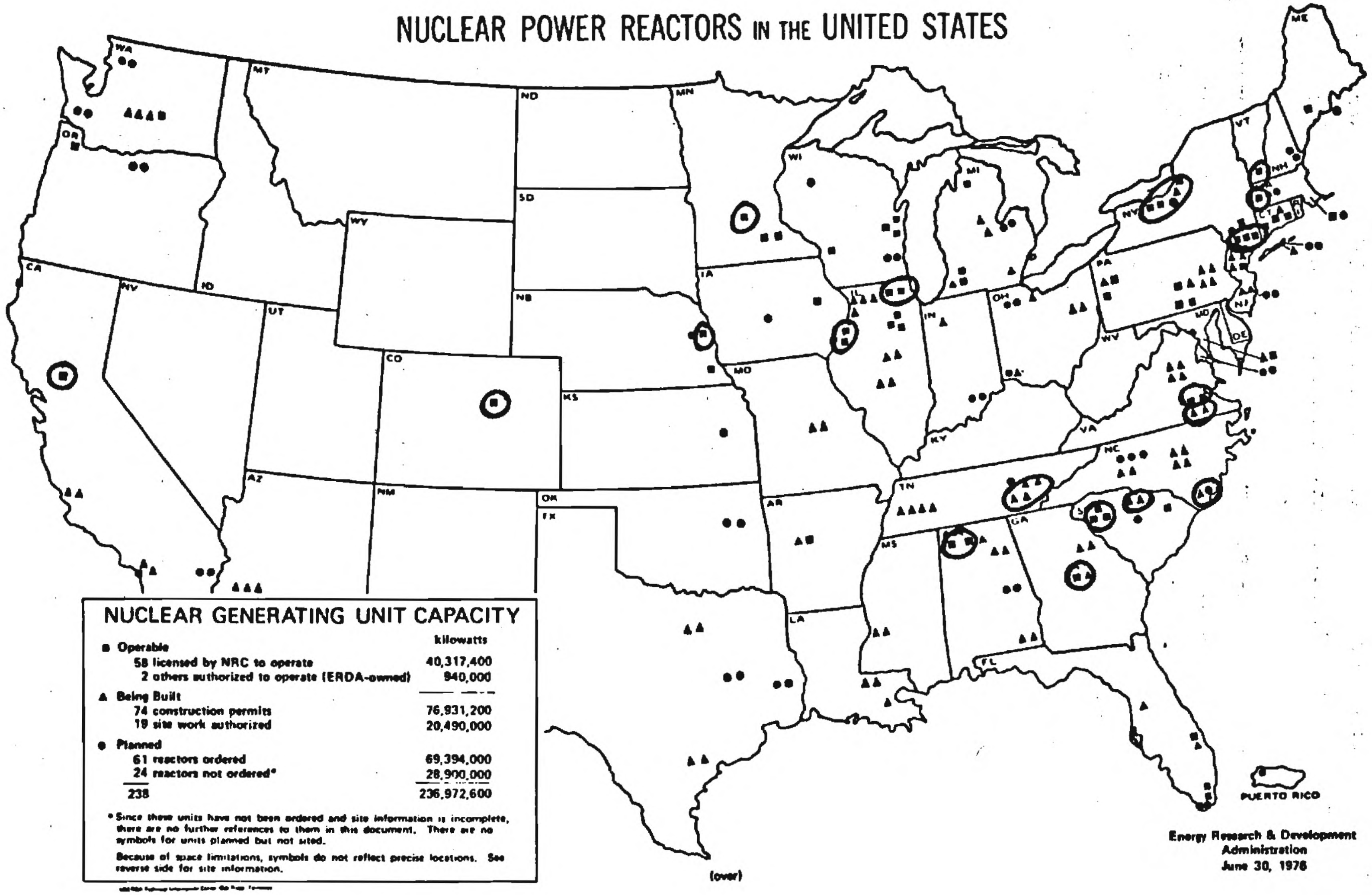

Figure 2-2. Location of Nuclear Power Plants under Review in This Project

That report recommended the adoption of the "critical pathway" approach, although there is no evidence that this recommendation was accepted and it has found no favor in the eyes of the U.S. AEC and NRC so far. Further guidance based on critical pathways and critical population groups was provided to the utilities in 1972 when the Environmental Protection Agency published its Environmental Radioactivity Surveillance Guide (7). Table 2-2, taken from that report, is fairly representative of the type of radiological surveillance programs encountered.

When in 1973 the AEC issued its proposed numerical guides to meet the "as low as practicable" (ALAP) criterion as applied to LWR's, their influence was felt immediately although they were not finally adopted as Appendix I to Part 50, Title 10 Code of Federal Regulations until May 1975. Although the ALAP, or its later version "as low as reasonably achievable" (ALARA) criterion applied primarily to effluent treatment, it implied that environmental concentrations now had to be measured at levels one or two orders of magnitude lower than previously anticipated. These changes are reflected in successive versions of Regulatory Guide 4.1 (8,9) which differ substantially in philosophy and detail. Additional guidance is also provided in Regulatory Guide 4.8, issued for comment in 1975 (10), which draws heavily on the EPA guide (7).

Table 2-3 summarizes some of the information obtained at plants that were visited regarding sample frequencies and number of sampling locations for some of the radiological analyses of interest. It is seen that by and large, actual sampling programs exceed the numbers suggested in the NRC and EPA guides, with the notable exception of soil samples which will be discussed below. Only one plant per utility is included in the table for easier comparison.

Several conclusions can be drawn from the data in Table 2-3:

- Most stations were already in compliance with the minimum program recommended for direct radiation measurement in Regulatory Guide 4.8 in 1974; in fact many had far more extensive programs, usually carried over from the pre-operational program.
- The Regulatory Guide suggests that measurement of accumulated radioactivity in soil be tied closely to other measurements of airborne pathways, but be done infrequently (once every three years). In contrast, most stations were monitoring

Table 2-2

OFFSITE SURVEILLANCE OF OPERATING LIGHT-WATER-COOLED NUCLEAR POWER FACILITIES

Operation or sample type	Approximate number of samples and their locations	Collection frequency	Analysis type[a] and frequency
Air particulates	1 sample from the 3 locations of the highest offsite ground level concentrations 1 sample from 1-3 communities within a 10-mile radius of the facility 1 sample from a location greater than a 20-mile radius in the least prevalent annual wind direction[d]	Continuous collection—filter change as required	Gross long-lived β at filter change[b] Composite for gamma isotopic analysis and radiostrontium analysis[c] quarterly
Air iodine	Same sites as for air particulates	Continuous collection—canister changes as required	Analyze weekly unless absence of radioiodine can be demonstrated
Direct radiation	2 or more dosimeters placed at each of the locations of the air particulate samples which are located at the 3 highest offsite ground level concentrations 2 or more dosimeters placed at each of 3 other locations for which the highest annual offsite dose at ground level is predicted[e] 2 or more dosimeters placed at each of 1-3 communities within a 10-mile radius of the facility[f] 2 or more dosimeters placed at a location greater than a 20-mile radius in the least prevalent annual wind direction[d]	Quarterly	Gamma dose quarterly
Surface water[g]	1 upstream 1 downstream after dilution (e.g., 1 mile)	Monthly (Record status of discharge operations at time of sampling)	Gross β, gamma isotopic analysis[h] monthly. Composite for tritium and radiostrontium analysis[c] quarterly
Ground water	1 or 2 from sources most likely to be affected	Quarterly	Gross β, gamma isotopic analysis[h] and tritium quarterly
Drinking water	Any supplies obtained within 10 miles of the facility which could be affected by its discharges or the first supply within 100 miles if none exists within 10 miles	Continuous proportional samples[i]	Gross β, gamma isotopic analysis[h] monthly. Composite for tritium and radiostrontium analysis quarterly[c]
Sediment, benthic organisms and aquatic plants	1 directly dowstream of outfall[j] 1 upstream of outfall[j] 1 at dam site dowstream or in impoundments[j]	Semiannually	Gamma isotopic analysis semiannually
Milk	1 sample at nearest offsite dairy farm in the prevailing downwind direction 1 sample of milk from local dairy representative of milkshed for the area	Monthly	Gamma isotopic analysis and radiostrontium analysis monthly[c]
Fish and shellfish	1 of each of principal edible types from vicinity of outfall 1 of each of the sample types from area not influenced by the discharges	Semiannually	Gamma isotopic analysis semiannually on edible portions
Fruits and vegetables	1 each of principal food products grown near the point of maximum predicted annual ground concentration from stack releases and from any area which is irrigated by water in which liquid plant wastes have been discharged 1 each of the same foods grown at greater than 20 miles distance in the least prevalent wind direction	Annually (At harvest)	Gamma isotopic analysis annually on edible portions
Meat and poultry	Meat, poultry, and eggs from animals fed on crops grown within 10 miles of the facility at the prevailing downwind direction or where drinking water is supplied from a downstream source	Annually during or immediately following grazing season	Gamma isotopic analysis annually on edible portions
Quality control[k]	Samples as required for accurate sampling and analysis		Minimum frequency—annually

[a] Gamma isotopic analysis means identification of gamma emitters plus quantitative results for radionuclides that may be attributable to the facility.

[b] Particulate sample filters should be analyzed for gross beta after at least 24 hours to allow for radon and thoron daughter decay.

[c] Radiostrontium analysis is to be done only if gamma isotopic analysis indicates presence of cesium-137 associated with nuclear power facility discharges.

[d] The purpose of this sample is to obtain background information. If it is not practical to locate a site in accordance with the criterion, another site which provides valid background data should be used.

[e] These sites based on estimated dose levels, as opposed to ground level concentrations where the dose may be affected by sky shine, high plumes, or direct radiation from the facility being monitored.

[f] These locations will normally coincide with the air particulate samplers used in the monitored communities.

[g] For facilities not located on a stream, the upstream sample should be a sample taken at a distance beyond significant influence of the discharges. The downstream sample should be taken in an area beyond the outfall which would allow for mixing and dilution. Upstream samples taken in a tidal area must be taken far enough upstream to be beyond the plant influence when the effluent is actually flowing upstream during incoming tides.

[h] If gross beta exceed 30 pCi/liter.

[i] Drinking water samples should be taken continuously at the surface water intake to municipal water supplies. Alternatively, if a reservoir is used, drinking water samples should be taken from the reservoir monthly. If the holding time for the reservoir is less than 1 month, then the sampling frequency should equal this holdup time. Increases in concentration of activation and/or fission products at these sources necessitate the analysis of tap water for the purpose of dose calculations. Additional analyses of tap water may be necessary to satisfy public demand.

[j] See figure 6 for locations on a stream. For facilities located on large bodies of water, sampling sites should be located at the discharge point and in both directions along the shore line.

[k] The Analytical Quality Control Service of the Surveillance and Inspection Division (SID) provides low-level radiochemical standards and interlaboratory services to State and local health departments, Federal and international agencies, and nuclear power facilities and their contractors. The Service operates several types of cross-check programs for the analysis of radionuclide in environmental media, such as milk, food, water, air, and soil. The samples are submitted on a routine schedule designed to fit the needs of each laboratory. Technical experiments are undertaken to permit detailed analyses of the accuracy and precision obtained by participating laboratories. In addition, low-level radioactivity standards are provided to the agencies participating in the various programs. Primary and secondary standardization is also performed as needed on those radionuclides not used on a routine basis.

Table 2-3

OFF-SITE ENVIRONMENTAL MONITORING PROGRAMS: SAMPLING LOCATIONS AND COLLECTION FREQUENCY

	SAMPLING LOCATIONS AND FREQUENCY		NUCLEAR POWER STATION OR COMPANY							
TYPE OF SAMPLE/ANALYSIS	EPA (7)	NRC/RG 4.8 (10)	A	B	C	D	E	F	G	H
Precipitation - Continuous Collection, Analysis for Gross β, Sr 90	0 --	0 --	2 M No Sr	0 --	2 M inc H3, 89, γ	2 M inc H3, γ	6 M	8 M inc 89, γ	0 --	2 M inc H3, No Sr
Milk - Gamma Isotopic, Sr 89, 90 Monthly, I-131 Weekly or Semi-Monthly	2 M No Sr unless Cs present	5 W or SM	2 W	3 SM or M inc H3	13 W inc H3	8 M No 89	4 W	5 W	2 M No 89	5 M
Sediments from Source of Water - Gamma Isotopic and Sr 90	3 SA No Sr	3-4 SA	7 Q inc β, 89	6 M in Summer inc β, 89	7 M inc β, 89, H3	8 SA inc β	13 Q inc 89	4 Q inc β, 89	14 Q inc β	6 SA
Surface Water - Gamma Isotopic Monthly, H3 and Sr 89, 90 Quarterly	2 Grab M & Q inc β	2 Composite	6 Composite β Weekly γ Quarterly	5 Composite No Sr	7 Grab M inc β	8 Grab D Composited W to Q	2 Grab M No γ or Sr	2 Grab M No H3 or Sr	6 Grab M No 89	9 Grab Q or SA No Sr
Direct Radiation Measurements - TLD's	8-10 Q	12-14 Q	10 Q	12 SM	36 M	32 M	14 Q	8 Q	22 M	12 Q
Airborne I-131 Collected by Continuous Samplers	5-7 W	5 W	10 W	8 W	7 W	9 W	6 W	8 W	5 W	0 --
Soil - Gamma Isotopic, Sr 90 on Collection	8-10 -- in situ γ	12-14 Once in 3 years	2 SA inc β, 89	4 M inc β, 89	13 M inc 89	6 SA inc β	3 SA inc 89	8 Q inc β, 89	8 Q inc β	6 A No Sr

LEGEND:

Collection Frequency

D - Daily
W - Weekly
SM - Semi-Monthly
M - Monthly
Q - Quarterly
SA - Semi-Annually
A - Annually

Type of Analysis

β - Gross Beta
γ - Gamma Isotopic
89 - Sr 89 in addition to Sr 90
H3 - Tritium

at only a few locations, but much more frequently; however, in conversations with plant staff it was usually explained that this phase in the programs was about to be cut back.

- Most stations collected and analyzed rainfall and dry deposition samples, beyond any recommendations in the guides.
- In recent years NRC has put more emphasis on the milk pathway than EPA did, but in 1974 most utilities had programs that were consistent with Regulatory Guide 4.8, except for the sensitivity required.
- On the average more sediment samples around the point of plant water discharge are analyzed than the minimum recommended in the guides.

While the surveillance programs suggested by the EPA and NRC guides are minimum programs and collection of more samples is not discouraged, these same recommendations in another sense represent a maximum envelope since certain pathways or sample media may not be applicable at some sites.

In general, one may conclude from this portion of the review that many utilities at this time had more elaborate and extensive surveillance programs than would be required strictly by NRC minimum guidelines or could be directly related to observable dose effects in some cases.

It was also found difficult to compare reported data from different plants and it was generally agreed that a more standardized format for reporting effluent releases and environmental impact would be desirable.

ASSESSMENT OF SPECIFIC SURVEY OPERATIONS

One way of evaluating the usefulness of the various components of a program is by assessing the contribution they make to the program objectives outlined in the Introduction and by an estimate of the cost and effort they represent. The cost contribution depends a little on the rest of the program and on whether sample collection is handled by plant staff or contractor personnel. The following represents a summary of the picture that emerged from the various interviews.

1. Milk Samples

The pasture-cow-milk-child pathway is generally seen to be a critical pathway, and the iodine dose to the thyroid is identified as a critical dose in site selection criteria (10 CFR 100). For that reason analysis of milk samples has received increasing attention in most surveillance programs. Sampling frequency has been widely increased to weekly samples; analyses are done for iodine-131, strontium-90, and increasingly strontium-89.

There are several problems associated with this activity. At this stage, in general, samples are collected from every herd within the milkshed inside a 10-15 mile radius from the plant, as well as from all single animals. An annual or semi-annual cow census identifying the location of each cow or group of cows, the number of cows, and the distance and azimuth of each dairy from the plant must be conducted for each plant. A similar census of goats is carried out regardless of whether their milk is used for human consumption. In some country areas the census and the regular sample collection involve considerable effort and call for appreciable tact and understanding by all parties concerned. While observation of activity of milk from cows in commercial production represents a sensible precaution, single animals kept as mainly family pets may have to be considered by a different standard, and difficulties arise when the power company becomes a major consumer of any milk produced.

The situation becomes more complicated with goats. In the few areas where goats were encountered, the collection of goat milk by a plant health physicist or contractor became one of the more unpopular tasks and one whose usefulness might be questioned, particularly if there is no significant human consumption of the milk.

In most cases the milk is shipped without preservative to the analytical laboratory and counted fairly promptly, in view of the short half life of iodine-131. This may make it possible to be more selective in the choice of milk samples under routine operating conditions and to step up sample collection only when plant occurrences make it advisable or there is a change in the feed pattern of the herds.

Iodine-131 concentrations in milk were generally around 1 pCi/ℓ, and in some cases where fluctuations were observed, these were correlated with fallout activities. Strontium-90 concentrations in milk ranged up to about 8 pCi/ℓ, cesium-137 to about 6 pCi/ℓ. These values compare with natural potassium-40 contents in the same samples of the order of 800-1400 pCi/ℓ. Table 2-4 a-d shows reported milk sample data from four power plants, selected at random to show the quality of the data, and the levels of activity encountered.

Table 2-4a

PART OF 1974 ENVIRONMENTAL REPORT: BROWNS FERRY

MILK

Location	No. of Samples	pCi/ℓ ^{131}I	^{137}Cs	^{40}K	^{140}Ba-^{140}La	^{90}Sr	^{89}Sr
Pasteurized Milk*							
Athens, Ala.	6	1.0	3.2	1292.7	0.7	4.7	1.4
Decatur, Ala.	6	ND	2.8	1301.3	0.4	5.2	0.7
Muscle Shoals, Ala.	6	1.2	0.9	1313.8	1.7	4.0	1.2
Average:		0.8	2.3	1302.6	0.9	4.6	1.1
Raw Milk**							
Farm B	26 (6)***	ND	2.9	1331.0	1.5	7.6	0.2
Farm H	26 (6)	ND	5.9	1385.8	0.2	4.5	1.1
Farm L	26 (6)	ND	1.5	1377.7	1.6	8.2	0.7
Farm T	26 (6)	ND	4.9	1300.5	0.9	4.4	0.7
Average:		ND	3.8	1348.8	1.0	6.2	0.7

*^{131}I analyzed by gamma scan.

**Chemical separation of iodine: Sensitivity for ^{131}I--0.5 pCi/ℓ at time of sample collection.

***^{131}I analysis weekly: gamma scan and ^{89}Sr, ^{90}Sr analyses monthly.

ND -- not detectable.

Table 2-4b

PART OF 1974 ENVIRONMENTAL REPORT: MONTICELLO

MILK

Sampling Location	Date of Collection	pCi/ℓ ^{137}Cs	pCi/ℓ ^{131}I	pCi/ℓ ^{90}Sr
Region #1 North of Plant Site				
Dwinger - 13.0 mi. @ 335°	1-16-74	3.0	<5.20	14.0
	2-13-74	6.2	<3.40	12.0
	3-13-74	6.6	<2.40	13.0
	4-10-74	4.0	<2.60	13.0
	5-15-74	8.6	<0.13	16.0
	6-12-74	19.0	<0.16	11.0
Kirchenbauer - 11.5 mi. @ 323°	1-16-74	4.0	<0.16	9.9
	2-13-74	4.3	<3.20	12.0
	3-13-74	4.6	<2.10	17.0
	4-10-74	6.0	<3.10	10.0
	5-15-74	6.6	<0.11	16.0
	6-12-74	15.0	0.40	9.9
Region #2 Southwest of Plant Site				
Kotilinek - 5.6 mi. @ 230°	1-16-74	<2.3	<4.90	6.8
	2-13-74	<2.4	<3.10	6.3
	3-13-74	5.6	<3.80	6.2
	4-10-74	<2.1	<3.90	5.4
	5-15-74	10.0	<0.28	7.2
	6-12-74	<1.8	<0.22	11.0
Vandergon - 8.3 mi. @ 247°	1-16-74	3.2	<6.20	2.6
	2-13-74	<1.8	<2.60	3.9
	3-13-74	<2.6	<4.70	4.2
	4-10-74	<3.1	<3.10	3.5
	5-15-74	12.0	<0.25	4.6
	6-12-74	3.3	<0.17	5.9
Region #3 South of Plant Site				
Holland - 8.1 mi. @ 199°	1-16-74	10.0	<5.70	4.0
	2-13-74	2.2	<2.20	3.1
	3-13-74	<2.4	<4.10	4.5
	4-10-74	2.2	<2.80	4.2
	5-15-74	3.6	<0.23	2.7
	6-12-74	10.0	<0.46	4.3
Hopkins - 7.6 mi. @ 193°	1-16-74	4.1	<5.80	3.6
	2-13-74	4.0	2.60	4.1
	3-13-74	2.5	<4.10	3.7
	4-10-74	1.7	<3.10	3.4
	5-15-74	<2.3	<0.26	3.7
	6-12-74	<2.3	<0.45	3.8

Table 2-4c

PART OF 1974 ENVIRONMENTAL REPORT: NINE MILE POINT

MILK SAMPLE DATA

Sample Identification	Collection Date	Nuclide	pCi/liter
Sample #1	8-27-74	I-131	2.0 ± 0.3 E+00
Sample #2	8-27-74	I-131	<1. E+00
Sample #3	8-27-74	I-131	<9. E-01
Sample #4	8-27-74	I-131	<9. E-01
Sample #4	AUGUST COMPOSITE	Sr-90 K-40 Cs-137	8.1 ± 1.3 E+00 <1. E 03 1.49 ± 1.01 E 01
Sample #1	AUGUST COMPOSITE	Sr-90 K-40 Cs-137	8.0 ± 1.3 E+00 <1. E 03 1.84 ± 1.32 E 01
Sample #3	AUGUST COMPOSITE	Sr-90 K-40 Cs-137	1.1 ± 0.2 E 01 <1. E 03 <7. E+00
Sample #2	AUGUST COMPOSITE	Sr-90 K-40 Cs-137	1.0 ± 0.2 E 01 <1. E 03 1.39 ± 0.86 E 01
Sample #4	9-3-74	Sr-89 Sr-90 K-40 Cs-137	<1. E 01 6.5 ± 0.7 E+00 8.6 ± 2.41 E 02 <9. E+00
Sample #3	9-03-74	Sr-89 Sr-90 K-40 Cs-137	<1. E 01 9.2 ± 0.8 E+00 1.29 ± 0.20 E 03 <9. E+00
Sample #2	9-03-74	Sr-89 Sr-90 K-40 Cs-137	<1 E 01 9.8 ± 0.8 E+00 9.42 ± 1.51 E 02 <9. E+00
Sample #4	9-3-74	I-131	<1. E+00
Sample #1	9-3-74	I-131	<1. E+00
Sample #3	9-3-74	I-131	<1. E+00
Sample #2	9-3-74	I-131	<1. E+00
Sample #4	9-10-74	I-131	<2. E+00
Sample #1	9-10-74	LOST	NOT ANALYZED

Table 2-4d

PART OF 1974 ENVIRONMENTAL REPORT: INDIAN POINT

FOOD (Human) -- PERIOD: 10/1/74 - 12/31/74

LOCATION	TYPE	FREQUENCY	AVERAGE QUARTERLY RESULTS	ANALYSIS RESULTS										REMARKS
				H-3	Sr-89	Sr-90	K-40	Cs-134	Cs-137	Co-60	I-131	Th-228	Ra-226	
MILK:														
Strawtown Dairy 7 Miles-SSW	Grab	Monthly		2.7	<0.06	0.02	11.7	11.7	<0.09		<0.08			Results in $\mu Ci/ml \times 10^{-7}$
Guard Hill Farm 10 Miles-ESE	Grab	Monthly		2.2	<0.06	0.06	13.7		0.09		<0.08			
Crowley's Dairy 20 Miles-North	Grab	Monthly		1.7	<0.06	0.03	11.8		<0.09		<0.08			
FISH:			Gross Beta											
Hudson River Various Locations	Grab	Monthly	1.90											Results in μCi/wet gram $\times 10^{-6}$ of flesh

Note particularly cesium-strontium values to which reference will be made in a later chapter. The tables show the varying formats; in some cases concentrations are reported directly, in others only by upper limits.

Since the iodine activity in milk is considered to constitute the critical pathway, it has been suggested from time to time that I-131 analyses should be conducted to a higher degree of precision and with improved detection sensitivity. This matter also will be reviewed in the next chapter. However, it seems pertinent to point out here that, although the additional concentration of the iodine in question is small when compared with that of potassium-40, its reconcentration in the thyroid still makes it the radionuclide of dominant concern.

2. Water Samples

Surface water samples above the plant water intake and below the plant at various strategic locations are usually obtained at weekly, monthly or quarterly intervals, either as a composite sample or as a random batch sample. These typically are analyzed for I-131, Sr-90, and occasionally for Sr-89 or tritium (see Table 2-3). In many cases samples are split and are screened also by gross alpha, gross beta and gamma-spectrum analyses. There seems to be general agreement that in themselves the gross alpha and beta determinations are of little value except to screen out background-level samples. The other analyses are mainly done for record-keeping purposes and to back up the liquid effluent monitors. Where the plant is situated on a major river or a tidal estuary, data obtained for radioactive and chemical discharges depend heavily on river run-off conditions and seasonal fluctuations.

Well water samples are collected where appropriate, and are analyzed as above. In most cases gross activities are dominated by radon daughters and K-40, and analyses are mainly done for record-keeping and reassurance of the public. Tritium analyses have shown significant readings in a few cases and should then be followed up.

3. Air Particulate Samples

Most plants have a number of sample locations, usually within a 5-mile radius, to collect particulate samples using continuous filter systems. Locations are limited by the need to have power available and to minimize theft or vandalism. For this reason company buildings or private homes are preferred to unattended sites. Cartridge charcoal filters are the preferred media, usually preceded by a standard dust filter. The charcoal filters are analyzed for I-131; the dust filters by gross beta analysis and in some cases by gamma-ray spectrometry. Installation and power consumption represent the main cost of these samples which are usually collected weekly.

Since plant effluents are usually fairly free of particulates the main use of the filter samples is for emergencies. If these samples do show activities during routine operations it would indicate a severe malfunction of the exhaust treatment or offsite interference. At some locations particulate samples were strongly affected by stack emissions from nearby coal-fired plants and such potential sources of confusion must be carefully identified. Since airborne activity, in any case, is usually dominated by radon and radon daughters, gross beta counts are not often of any use. These samples are also most susceptible to fallout from nuclear tests, up to 2-3 years after any atmospheric tests have taken place.

Similar considerations apply to precipitation samples which are gradually discontinued at most plant sites. They are highly dependent on external factors and only rarely can they be effectively correlated with plant operations.

4. Soil Samples

The routine analysis of soil samples was discussed at most plants and it was generally agreed that such samples, as currently obtained, serve little real purpose. Sampling schedules have typically gone from one-year to three-year intervals; the locations of the sampling sites are usually at some arbitrary locations, at two to ten farms or pastures, and usually there is no specified method of sample collection such as those recommended in the HASL Procedures Manual (11,12). There is no provision for selecting sample conditions with regard to granularity or wetness. At all sites so far observed, soil samples invariably showed K-40 and radionuclides from worldwide fallout.

It is recommended that soil sampling be discontinued after the end of the first operational year, except near waste disposal areas, and be conducted only under closely specified and reproducible conditions whenever its resumption is dictated by some suspected or unanticipated abnormal release of activity from the plant.

5. Food Crops and Forage Samples

A similar situation pertains to vegetation samples. These are usually collected from farms and private gardens surrounding the plant site during the growing season. Forage crops are usually collected by hand clipping all growth inside a hula hoop or similar boundary placed on the ground. In view of the importance of the iodine-milk pathway, forage samples from cattle pastures are analyzed for I-131 and Sr-89,90; however, reconcentration in the milk is probably a more effective indicator. In practice, concentrations in vegetation are too low to be detectable against existing background, and such analyses mainly serve a record-keeping function; as regards public reassurance, sample collection in private gardens is more likely to cause concern than relief. Only crops known to concentrate fission or corrosion products strongly would merit extensive attention.

6. Terrestrial Species

The surveillance programs at many plants provide for a radiological analysis of selected organs or meat samples of animal, wildlife and bird samples, typically quarterly or semiannually.

Some plants have made arrangements with state authorities to receive wildlife samples (deer, squirrels, rabbits, opossums, etc.) killed by traffic within a 10 mile radius of the plant. At others periodic rabbit or squirrel hunts have to be organized for the purpose. During several interviews strong doubts were expressed concerning the usefulness of these activities in the absence of any significant releases. The species concerned usually cover too great a range to be clearly associated with feeding grounds close to the plant, many people felt repugnance at having to kill squirrels or rabbits, and the statistical value of the data obtained seemed to be questionable. This aspect of the radiation surveillance program should be re-assessed.

In cattle-raising areas arrangements can usually be made to obtain beef livers, thyroids and bone specimens from a slaughter-house for analysis, though occasionally difficulties arise in tracing an animal. Since milk samples provide better concentration factors, it may be sufficient to rely on them for uptake monitoring and analyze beef only when unusually high levels of effluent release have been recorded.

7. Aquatic Samples

Samples of mud, silt and benthic organisms are usually analyzed monthly, quarterly, or semiannually and are considered a sensitive indicator of any accumulation of radionuclides in aquatic biota.

The collection of these samples is usually tied in with the ecological program since the samples may be collected by dredging or by the exposure of rough bricks that encourage algal growths. Table 2-5 is an example of the range of activity for major fission products observed in aquatic and soil samples at one station. The principal cost in collecting these samples is usually included in the ecological program and will be discussed there.

8. Fish and Mollusks

At many stations the collection and classification of fish entrained on the intake screen is a major activity that may occupy one or two people, full time in a few cases. Some fish can be set aside weekly or monthly for radiological analysis. In addition, larger fish are caught by angling, seining or trawling, and this is a fairly popular activity as long as the weather is fine. The purpose of these fish catches is threefold: to observe any significant changes in the fish population as a result of the thermal or chemical effluents from the plant, to monitor commercially valuable aquatic species, such as crabs, lobster or clams; and to check any radioactive accumulation in such animals or fish that are commercially important or for game fishing.

The radioactive analysis, done on monthly or quarterly specimens, presents no particular problem. A real problem does exist in the daily fish counts. This amounts to a daily collection and analysis by species, size and weight of all fish caught on the coolant intake screens. Table 2-6 is a representative example, taken at random, of the type of data obtained. In that case 65,800 fish were collected and counted in one month, which sounds like a lot of fish until it is seen that their average weight was 1/100 lb or 4.5 gram, i.e., these are mainly fish fry. In other words the plant collected about 5-60 lbs of fish fry per day, barely a pail full out of a vast, but quite undetermined total population in the river.

Table 2-5

YANKEE ATOMIC ELECTRIC COMPANY - OFFSITE ENVIRONMENTAL RADIOLOGICAL MONITORING
SUMMARY OF ANALYSES FOR THE PERIOD JULY 1, 1974 - DECEMBER 31, 1974

Type of Media Sampled (Number of Locations)	Total Number of Samples	Analysis Performed	For Sampling Point with Highest Average Level for the Period: Highest	Lowest	Average	Sampling Point with Highest Average Level	Number of Locations Significantly Above Background
Soil (9)	18 Grab Samples (Aug. and Nov. at each station)	Gross Alpha (pCi/g)	(1.6±0.3)E+1	(1.1±0.5)E+1	(1.4±0.4)E+1	Station SV2,SV4	0
		Gross Beta (pCi/g)	(3.8 0.6)E+1	(2.8±0.2)E+1	(3.3±0.4)E+1	Station SV9	0
		Sr-90 (pCi/g)	(1.5±0.1)E+0	(8.6±1.6)E-1	(1.2±0.1)E+0	Station SV7	0
		Gamma Spectrum(pCi/g)					
		Be-7	(1.5±0.4)E+0	<2.E-1	(8.5±2.5)E-1	Station SV3	0
		K-40	(1.7±0.2)E+1	(9.7±1.0)E+0	(1.3±0.15)E+1	Station SV3	0
		Mn-54	(1.3±0.4)E-1	(7.6±2.9)E-2	(1.0±0.2)E-1	Station SV1	1
		Co-58	<5.7E-2	<2.E-2	<3.9E-2	Station SV1	1
		Co-60	(9.6±1.0)E-1	(8.5±0.9)E-1	(9.1±1.0)E-1	Station SV1	1
		Zr-95	(1.9±0.9)E-1	<4.E-2	(1.2±0.6)E-1	Station SV3	1
		Ru-106	(6.6±3.9)E-1	<2.E-1	(4.3±2.5)E-1	Station SV3	1
		Ag-110m	(1.3±0.5)E-1	<2.E-2	(7.5±3.0)E-2	Station SV1	1
		Cs-134	(7.4±3.0)E-2	<2.E-2	(4.7±2.0)E-2	Station SV2..	3
		Cs-137	(1.9±0.2)E+0	(1.2±0.1)E+0	(1.6±0.15)E+0	Station SV3,SV9	0
		Ce-144	(8.0±2.9)E-1	<2.E-1	(5.0±2.0)E-1	Station SV3	0
		Ra-226	(1.4±0.7)E+0	(1.1±0.4)E+0	(1.3±0.55)E+0	Station SV5	0
		Th-228	(8.8±1.1)E-1	(8.1±1.0)E-1	(8.5±1.1)E-1	Station SV9	0
Aquatic Plants (3)	6 Grab Samples (Aug. and Nov. at each station)	Sr-90 (pCi/g-wet)	(3.1±0.2)E-1	(2.8±0.5)E-1	(3.0±0.4)E-1	Station FA1	0
		Gamma Spectrum(pCi/g-wet)					
		Be-7	(9.9±1.6)E+0	(3.2±0.4)E+0	(6.6±1.0)E+0	Station FA3	0
		K-40	(5.6±2.7)E+0	(2.5±0.8)E+0	(4.1±2.7)E+0	Station FA3	0
		Co-60	(2.5±1.1)E-1	<2.E-2	(1.4±0.6)E-1	Station FA3	0
		Mn-54	(4.7±2.6)E-2	<2.E-2	(3.4±1.8)E-2	Station FA2	0
		Zr-95	(4.4±2.3)E-1	(1.8±0.8)E-1	(3.1±1.6)E-1	Station FA3	0
		Ru-103	(3.9±1.6)E-1	<6.3E-2	(2.3±1.4)E-1	Station FA3	0
		Ru-106	(5.8±2.3)E-1	<4.6E-1	(5.2±2.3)E-1	Station FA1	0
		Cs-137	(8.3±1.3)E-1	(1.6±0.3)E-1	(5.0±0.8)E-1	Station FA3	0
		Ce-141	<2.3E-1	<4.E-2	<1.4E-1	Station FA2	0
		Ce-144	(4.0±1.0)E+0	(3.7±0.4)E+0	(3.8±0.8)E+0	Station FA3	0
		Th-228	(5.2±0.8)E-1	(9.9±1.1)E-2	(3.1±0.4)E-1	Station FA1	0
Milk (2)	12 Grab Samples (monthly from each station)	Sr-90 (pCi/l)	(2.0±0.1)E+1	(6.3±1.0)E-1	(1.4±0.2)E+1	Station MI1	0
		I-131 (pCi/l)	<2.E+0	<5.E-1	<8.3E-1	Station MI2	0
		Gamma Spectrum(pCi/l)					
		K-40	(1.4±0.3)E+3	(1.1±0.2)E+3	(1.3±0.2)E+3	Station MI1	0
		Cs-137	(4.3±1.0)E+1	<1.E-1	(2.5±0.7)E+1	Station MI1	0
		C-14	(1.0±0.1)E+1	(9.3±0.5)E+0	(9.7±0.6)E+0	Station MI1	0
Thermoluminescent Dosimeters(22)	264 (Integrated Monthly Samples - 4 readings/site/month)	Monthly Exposure (mR/month)	32.3±1.6(*6)	30.5±0.4(*6)	31.3±1.3 (*5)	Station 18(	9

Table 2-5 (Continued)

Type of Media Sampled (Number of Locations)	Total Number of Samples	Analysis Performed	For Sampling Point with Highest Average Level for the Period: Highest	Lowest	Average	Sampling Point with Highest Average Level	Number of Locations Significantly Above Background
River Sediment (14)	28 Grab Samples (Aug. and Nov. at each station)	Gross Alpha (pCi/g-dry)	(2.7±0.8)E+1	<5.4E+0	(1.6±0.5)E+1	Station SE10	0
		Gross Beta (pCi/g-dry)	(5.2±0.3)E+1	(2.9±0.2)E+1	(4.1±0.3)E+1	Station SE10	0
		Sr-90(pCi/g-dry)	(1.0±0.1)E+0	(2.9±0.6)E-1	(6.5±0.8)E-1	Station SE1(	0
		Gamma Spectrum(pCi/g-dry)					
		Be-7	(9.6±3.1)E-1	(5.7±2.9)E-1	(7.7±3.0)E-1	Station SE6	0
		K-40	(2.1±0.2)E-1	(1.1±0.1)E-1	(1.6±0.2)E-1	Station SE1	0
		Co-60	(1.8±0.2)E+0	<2.E-2	(9.1±1.1)E-1	Station SE1	2
		Zr-95	(5.8±0.7)E-1	<4.E-2	(3.1±0.6)E-1	Station SE2	0
		Ru-106	(4.3±2.2)E-1	<2.E-1	(3.2±1.6)E-1	Station SE6	0
		Cs-134	(9.7±1.0)E-1	<2.E-2	(4.9±1.0)E-1	Station SE3	1
		Cs-137	(7.6±0.8)E-0	(1.4±0.4)E-1	(3.9±4.2)E+0	Station SE1	0
		Ce-144	(3.1±2.0)E+0	<2.E-1	(1.7±1.0)E+0	Station SE5	0
		Ra-226	(3.2±1.4)E+0	(7.5±4.3)E-1	(2.0±0.9)E+0	Station SE1	0
		Th-228	(3.1±0.4)E+0	(5.9±0.7)E-1	(1.9±0.3)E+0	Station SE8	0
		Mn-54	(1.4±0.6)E-1	<2.E-2	(8.0±0.8)E-2	Station SE1	2
Fish (3)	6 Grab Samples (Aug. and Nov. at each station)	Sr-90(pCi/g-wet)	(4.6±0.1)E+0	(6.5±1.1)E-1	(2.6±0.1)E+0	Station FA3	0
		H-3 (Bound Water pCi/g-wet)	(1.7±0.2)E+0	(2.0±0.2)E-1	(9.5±1.1)E-1	Station FA2(	0
		Gamma Spectrum(pCi/g-wet)					
		K-40	(2.7±0.8)E+0	(2.5±0.4)E+0	(2.6±0.6)E+0	Station FA2(	0
		Cs-137	(1.1±0.3)E-1	<2.E-2	(6.7±2.0)E-2	Station FA1(	0

FOOTNOTES FOR TABLE 1

*1 All data listed (except TLD measurements made by Rowe personnel) were measured by the analytical contractor, Teledyne Isotopes, Westwood, New Jersey, and represents the measurement (or average of a number of measurements) ±2 sigma counting error (or average of the 2 sigma error). In any case where the measured value was less than the 3 sigma counting error, the value is reported as less than the 3 sigma error. Note 1.0E-1 = 1.0×10^{-1}.

*2 Averages for all media computed by including values reported as less than a detection limit as if it was actually at the detection limit. Thus all averages are upper limit values.

*3 Numbers supplied represent detection limits for Iodine-131 which varies from week to week depending on elapsed time before analysis, and volume of air sampled. All cartridges for the period were analyzed by radiochemical separation of iodine from the charcoal and low background beta counting.

*4 Less than minimum detectable activity (MDA). See Table X (Environmental Sample Detection Sensitivities by High Resolution Ge(Li) Spectroscopy).

*5 TLD average represents 6 month mean ± statistical sample standard deviation.

*6 Value shown is the average of a single TLD badge readout ± standard deviation of four replicate readout areas.

Table 2-6

DAILY FISH COUNTS FOR INTAKE SCREENS (SEPTEMBER 1974) - INDIAN POINT UNIT NO. 2

DAY	Species 01	02	03	04	05	07	10	13	14	15	19	22	25	28	29	30	32	35	34	39	45	Total Number	Total Weight (lb)
1	8	1462	4	2		1	2	61				1		1	1	5	309	16		1	3	1877	19.36
2	11	2132	17	10			9	346	1			20		1		21	967	41		2	73	3651	35.99
3	3	1440	12				6	77				19			1	6	916	41			82	2603	25.59
4	5	1614	15	3			7	335				29	4			27	1125	68			15	3247	32.69
5	48	1788	28	11		1	6	673				29	10	1		40	2303	103	2	14	27	5084	61.82
6	3	513	18	6	1	1	6	356				26	6	1	1	17	661	80		4	10	1710	25.53
7	8	233	2	4			4	259				2		1		11	652	55		7	6	1244	15.85
8	2	113	2	5			4	31			1	3	3		1	4	767	32		2	8	978	10.90
9		105	2	1			3	14					3			3	487	31		9	14	672	5.92
10		218	2	3			1	62				8	2			2	345	42		9	5	699	7.20
11	6	1781	4	1	1			201	1			18	2	1		19	1312	164		5	17	3533	30.83
12	18	1175	1	7			1	262			1	13				24	1971	119	1		36	3629	36.82
13	8	973	3	1			4	122		1		11				11	1559	78		5	16	2792	29.91
14	14	908	2	5			2	81				8		2		11	1854	19		33	29	2968	29.99
15	17	685	15	1	1	1	2	167				17		1		47	2816	150	2		13	3935	44.29
16	24	872	15	3			8	184				15		1		26	4492	139	1	1	5	5786	56.84
17	9	247	8	1				122				7				23	1890	115				2422	26.41
18	20	257	16	2		1	3	237				26	5			26	5293	204		1		6091	60.22
19	13	205	12	1			2	170				14	1			19	2739	89	2		2	3269	35.10
20	19	223	11	1		1	2	74				15				15	2211	178	2	2		2754	29.05
21	19	236	13	2				106				15	3			18	2462	200		2		3076	29.26
22	2	91	2	1			1	12				12	1			19	318	459				918	7.96
23	8	231	5		1		4	37				11	4			11	202	217		4	1	736	8.32
24	2	201	2	1				9				11	20			4	7	117	2	2		378	5.79
25	3	86	1					3				5				2	72	55		2		229	1.90
26	2	65		1				1				3				3	9	28	1	1		114	.96
27	5	207	7	1			1	25				8				6	47	151		1	3	462	4.69
28	6	90	1	4			1	33				1				4	40	32		1	2	215	3.93
29	4	68	3	2				16				3					15	26	1	1	4	143	3.68
30	6	91	6		3		1	47				9		5		6	11	406			4	595	7.45
TOTAL	293	18310	229	80	7	6	80	4123	2	1	2	359	64	15	4	430	37852	3455	14	109	375	65810	694.25

The effort of sizing, identifying and weighing many thousand small fish per day is a major expenditure of manpower. Although the results are of some scientific interest, it is proposed that such fish counts be discontinued, except for special reasons, at most plants. In cases where exceptionally large entrainment losses occur the money saved might more appropriately be devoted to redesigning the intake area.

9. External Radiation Measurements

The integrated ambient radiation exposure, due to natural radiation sources and any released airborne activity, is usually monitored by means of thermoluminescent dosimeters (TLD). The TLD's are changed and read variously at weekly to quarterly intervals and should be mounted at a moderate height above the ground in a dry, shady location. The reading of the TLD's is either done by a special contractor, not necessarily the same as the radioanalytical contractor, or by company staff preferably at a location away from the high background of the nuclear reactor. Some companies have installed fairly elaborate computer facilities to handle TLD's from several sites and to keep track of the sensitivity characteristics of each dosimeter. The TLD's provide the only record of any potential dose from noble gas releases at ground level locations and, as Table 2-3 shows, their number may vary greatly.

The organizational aspects of this dosimetry will be discussed later. To our knowledge no plant-related excess exposures have been reported so far in routine measurements.

10. Action Levels

The futility of compiling large numbers of data of an essentially negative character for a long time has been recognized for several years. Several plants, in their Tech Specs, have provisions for stretching out the radiological surveillance program as long as readings remain near background. This is illustrated in Table 2-7, which shows a sampling schedule where the sample frequency can be varied with the "action level." During the start of operations Action Level 3 pertains, with relatively frequent sample collections. If the emission values, as measured at the plant outlet point, remain below 10% or 3% of authorized values, sampling schedules according to Action Levels 2 or 1, respectively, come into force and remain as long as

Table 2-7

ENVIRONMENTAL RADIATION SURVEILLANCE PROGRAM SCHEDULE (FORT ST. VRAIN)

Exposure Routes or Media & Sample Types (Number of locations)	SAMPLING FREQUENCIES AND ANALYSES - by Action Levels, based upon actual emissions as percentages of release rates authorized by 10 CFR 20		
	Action Level 1: Less than 3%	Action Level 2: 3% to 10%	Action Level 3: Greater than 10%
EXTERNAL EXPOSURE TLD Chips (36 locations)	Average mR/day determined by QUARTERLY cumulative exposures; collection and analysis in rotation of 1/3 of all TLDs MONTHLY.		Average mR/day determined by MONTHLY analysis of all TLDs.
ATMOSPHERE Membrane filters for particulates; charcoal cartridges for iodine. (7 locations)	Gross beta, every filter, WEEKLY; gamma spectrum of filter and cartridge composites, MONTHLY.	Same as for Level 1, plus gross alpha on one weekly set of filters, MONTHLY.	Gross alpha and beta, every filter; gamma spectrum of filter and cartridge composites, all WEEKLY.
Tritium oxide (2 locations: F1 & F4)	Specific activity of tritium in atmospheric water vapor by passive absorption and liquid scintillation counting. QUARTERLY	MONTHLY	WEEKLY
WATER Potable water (2 locations)	Gross beta, tritium and gamma spectrum analyses; Facility area and nearest off-site supply (shallow wells at town of Gilcrest, 6 miles northeast). QUARTERLY	MONTHLY	plus Sr 89, 90 analysis MONTHLY
Precipitation (2 locations: F1 & F4)	No collection or analyses of precipitation at Level 1.	Gross beta, MONTHLY	Gross beta, tritium and Sr 89 & 90, MONTHLY; gamma spectrum of composite, QUARTERLY.
Surface water & silt (7 locations)	Gross beta, tritium and gamma spectrum, QUARTERLY.	Same as for Level 1, but MONTHLY.	Same as for Level 2, plus Sr 89 & 90 analyses, MONTHLY.
FOOD CHAINS Soil, forage & crops (13 locations)	Tritium and gamma spectrum analyses of forage and crops in the most probable routes to man. QUARTERLY, as available (i.e., spring, summer and fall).	MONTHLY during growing season (i.e., approx. April to October).	Same as Level 2, plus Sr 89 & 90, plus concurrent soil samples analyzed for the same nuclides, MONTHLY during growing season.
Beef cattle (1 location: Facility Area)	No analysis of beef at Level 1.	Gamma spectrum, tritium and Sr 89 & 90 analyses on one meat sample from beef raised in Facility Area; ANNUALLY, at end of grazing season (i.e., late fall).	Same as for Level 2, plus total body count of 2 to 4 animals from Facility Area, QUARTERLY.
Milk (13 locations)	Tritium, gamma spectrum and Sr 89 & 90 analyses on composite: Facility Area only, QUARTERLY.	Facility, Adjacent and Reference Areas; MONTHLY during pasture season, otherwise QUARTERLY.	Same as for Level 2, but WEEKLY during pasture season, otherwise, MONTHLY.
AQUATIC BIOTA (2 streams, above and below discharge points)	Gross beta and gamma spectrum analyses of composites of each of 4 categories: (1) suspended organisms, (2) benthic organisms, (3) vascular plants and (4) fish. QUARTERLY, as available.	MONTHLY during summer; otherwise QUARTERLY, as available.	Same as for Level 2, plus Sr 89 & 90 analyses.

effluent levels stay low. This approach is more sensitive to actual operating conditions, and it is recommended that it should be incorporated in some similar fashion in most future Tech Specs.

ECOLOGICAL (BIOLOGICAL) SURVEYS

The biological surveillance programs at the various plants vary greatly in scope and complexity. To some extent this is due to the evolution of such programs and to their less formalized nature in the absence of any regulatory guidelines on the subject. In some cases the scope and cost of the program are due to a commitment by the plant operator to support a research program going beyond purely plant-related environmental impact. In other cases the biological programs seemed to be directed mainly to establish the need, or otherwise, for cooling towers to supplement existing cooling systems and to determine alternative impacts. The organization of this work varied similarly. In many cases pre-operational activities were simply continued into the operational phase. If they were limited to measurements of the thermal plume and the collection of aquatic species, they were often conducted by a small staff of biologists directly attached to the plant. In other cases more elaborate programs on plant and animal life, on algae and benthic organisms, and on marine organisms, where applicable, were conducted under contract by university staff or private research institutions. Some larger companies, such as TVA, have set up their biological research groups to carry out such work both for the pre-operational and operational stages. The result has been the accumulation of impressive local ecological data often far exceeding any previously available. However, it may be argued that such research is mainly a contribution to educational activities and scientific knowledge and may have little to do with the actual operation of the power plants. Such research-oriented programs are being supported by some companies at a cost of $150,000 to $350,000 per year. The following surveillance activities are of major importance.

1. Thermal Plume Measurements

Thermal discharges are monitored both for once-through cooling and in reservoir lakes to monitor changes in water quality. Depending on state water quality criteria maximum temperature rises are specified at a 5-foot depth, at surface, or averaged over a depth profile, subject to season-dependent maximum temperatures. At most plants temperature is monitored continuously at two or three fixed near-shore locations. In addition, at some plants thermal plume measurements are conducted to define isothermal contours. Table 2-8 and Figure 2-3 illustrate the data obtained and the isothermal contours for a selected plant and date. Depending on plant Tech Specs, such measurements, which involve appreciable effort, may be done at monthly to bimonthly intervals.

2. Aquatic Biota

To monitor the occurrence of any thermal or chemical stress from plant operations, most programs study selected indicator species. Samples of phytoplankton, zooplankton and benthos are collected quarterly or seasonally and studied for numbers, species diversity, productivity and biomass. Except under unusual conditions of heat release or plant shutdown it is usually difficult to obtain close correlation between ecological data and plant operations. More frequent sample collection, as practiced at some plants, seems to be rarely warranted.

3. Fish

Reference has already been made to the census of entrainment losses of fish. During the major spawning period, the entrainment of fish eggs and larvae in the cooling water system is studied, using stationary nets or seines. There is a wide variation in the frequency of sampling and methods of fish collection. For plants located on major rivers it seems to have been well established that entrainment effects are quite small.

In a few cases fish kills have been observed near power plants. These have either been shown to be due to cold shock, i.e., sudden withdrawal of warm water due to plant shutdown in winter, or to excessive release of plant chemicals, or totally unrelated to the power plant at all.

4. Crop and Pasture Surveys

At some plants studies are done on the effects of cooling tower plumes and salt deposition on crop lands. These studies are directed specifically to evaluate the impact of cooling towers in certain locations and their cost should be assigned to that assessment rather than the general environmental monitoring program.

Table 2-8

TRIPLE-DEPTH THERMAL PLUME MEASUREMENTS

FORT CALHOUN STATION - NOVEMBER 25, 1974

	T, °F Distance from Nebraska Bank, Feet					
	10	25	50	100	150	200
Transect No. 1 (RM646.0)						
Surface	0	0	0	0	0	0
One-half depth	0	0	0	0	0	0
Bottom	0	0	0	0	0	0
Transect No. 1.5 (RM645.9)*						
Surface	15.3	4.8	.6	0	0	0
One-half depth	15.5	5.8	.4	0	0	0
Bottom	15.5	1.3	.4	0	0	0
Transect No. 2 (RM645.6)						
Surface	5.0	3.7	.9	.3	0	0
One-half depth	5.1	3.7	.7	.2	0	0
Bottom	5.1	3.7	.9	.2	0	0
Transect No. 3 (RM644.8)						
Surface	2.6	2.2	.4	0	0	0
One-half depth	2.6	2.2	.4	0	0	0
Bottom	2.6	2.0	.7	0	0	0
Transect No. 4 (RM641.4)						
Surface	1.3	1.3	1.2	.9	.7	.4
One-half depth	1.3	1.3	1.2	.9	.7	.4
Bottom	1.3	1.3	1.2	.9	.7	.4
Transect No. 5 (RM640.2)						
Surface	1.0	.8	.8	.3	.2	0
One-half depth	1.0	.7	.7	.3	.2	0
Bottom	1.0	.8	.8	.3	.2	0

*Location of Plant Thermal Discharge
RM--River Mile

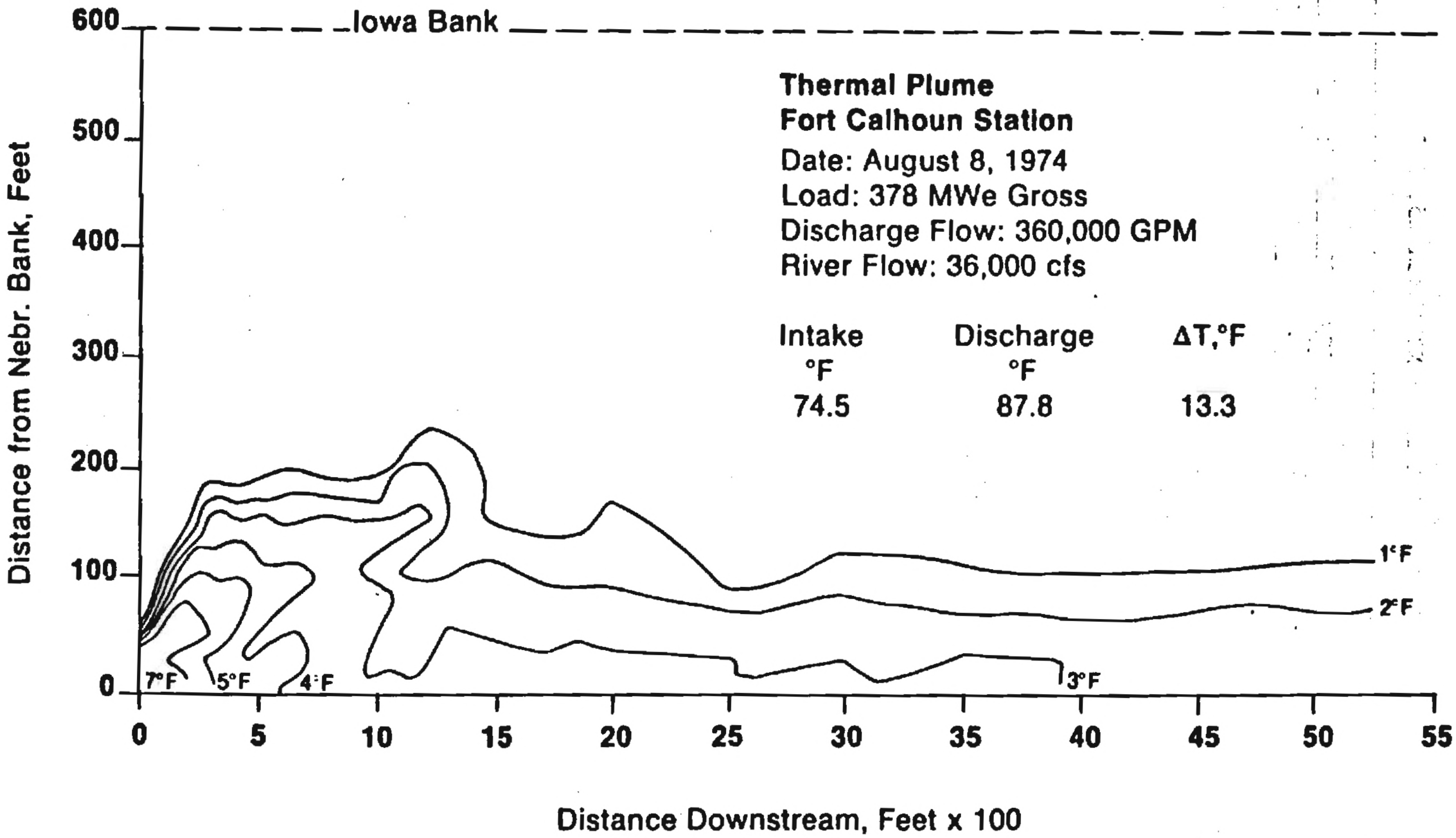

Figure 2-3. Example of Thermal Plume Contours (Fort Calhoun)

Additional studies are usually concerned with herbaceous cover, standing crops, and leaf damage. In most cases any variations observed tend to be more dependent on winter temperatures and insect survival than on power plant operations.

5. Birds, Mammals, Amphibia and Reptiles

The construction of the plant will cause changes in habitat to various animal species at the plant site and along transmission line rights-of-way. During the pre-operational stage data on populations and species diversity are normally obtained over a 2-3 year period. Unless these include any rare or endangered species, the census of any other species may be regarded as being mainly of scientific interest. Land clearing is bound to affect nesting sites for some bird species and restrictions on hunting in the plant area may affect several mammal species. The long-range value of such studies over the operating life of the plant may need periodic review.

6. Meteorological Surveys

Most power plants are required to erect a meteorological tower that exceeds in height all other structures at the site. This provides opportunities for continuous measurements of wind speed and direction, temperature profiles, precipitation and atmospheric radiation levels. This information is usually automatically recorded, requires little additional manpower and helps in updating plant safety estimates and emergency programs. Experience has shown that this equipment requires checking and recalibration at reasonable intervals. The data obtained may be used to update estimates on the dispersion of airborne effluents and any dose values from the plume. At plants where a significant portion of atmospheric release occurs from multiple roof vents, it may be particularly important to obtain such data, at least at the earlier stages of the operational phase.

ORGANIZATION OF THE SAMPLING PROGRAM

The procedures and responsibilities for sample collection, biological evaluation and radioassay vary greatly from plant to plant. Only rarely, however, is the plant's Health Physics staff involved in such activities to any great extent. Table 2-9 summarizes the various options in use. Companies operating a single nuclear power plant in general tend to contract out both biological and radiological assay work. In some cases, the contractor also collects

Table 2-9

RESPONSIBILITIES FOR SURVEILLANCE PROGRAMS

	Option 1	Option 2	Option 3	Option 4
Sampling				
Air				
Water				
Milk	HP	CL	RC	
Crops	(milk CL)			
Soil				
TLD			HP	HP or SB
Fish				
Aquatic biota	SB	BC	BC	
Mammals				
Thermal	SB or HP			
Analysis				
Air				
Water				
Milk	RC		RC	
Crops & food		RC		CL
Soil				
TLD	CL		CL or RC	
Fish	SB			
Aquatic biota	BC	BC	BC	BC or SB
Mammals				

HP	Plant Health Physics
SB	Staff biologist (plant or HQ)
CL	Central company lab
BC	Biol. contractor
RC	Radiol. contractor

samples; however, in most cases it is found more economical for plant staff to collect the samples and ship them to a contractor. Where a biology staff is employed, e.g. for fish analysis, they usually also collect environmental samples for outside analysis.

Utilities that operate three or more nuclear plants increasingly plan to set up a central laboratory to handle samples at least for radioassays; in some cases that facility may also deal with ecological samples. The economics of this decision will be discussed in a later chapter.

The degree of involvement of the plant health physics staff in the environmental programs is a major policy decision. As we have seen, some sampling functions may demand significant manpower, and this has to be provided without cutting into essential health physics coverage on site. Occasional sample collection, such as soil samples or beef samples, can be handled by plant staff or the contractor depending on contractual arrangements. Changing filters or air samplers and collecting TLD's is often done most easily by Health Physics staff. However, a reasonable priority for instrument repair and maintenance by plant electrical departments must be assured for the plant to meet its legal commitments in this respect.

The reading of thermoluminescent dosimeters falls into a separate category. Because of the high internal background in the plant and the different sensitivity ranges for personnel dosimeters and environmental monitors, it may not be practical to read the latter at the plant even though facilities exist there. Many companies seem to prefer to read their own TLD's, off site, even though all other functions are contracted out. This fulfills the purpose of more rapid and internal control of radiation levels.

One argument for contractor-operated assay services is that it preserves independence of analysis and reporting from company interests. On the other hand, company operation of central assay labs may result in faster turnaround and more flexibility if it appears desirable to run more samples of a certain type.

In both cases it is important to send some check samples through the analytical process to confirm its reliability and to detect accidental cross contamination. Such samples may be samples of known content or duplicates of samples of unknown content. Some check samples have been supplied routinely by the U.S. Environmental Protection Agency; however, the opinion was frequently expressed that those samples were too radioactive to provide a valid check and posed a danger of contaminating equipment. Some proposals have been made for the preparation of low-level reference material by the National Bureau of Standards or some other organizations. Such development would probably have to be supported financially on an industry-wide basis.

EMERGENCY SURVEY PROCEDURES

Although this was not a principal objective of the present project, some enquiries were made regarding the integration of existing surveillance programs with emergency programs. In general it was found that there was little connection. Typically, some survey equipment is stored at a location off-site under nominal control of the Health Physics staff. In case of an incident resulting in a release of activity from the plant, the civil state authorities are informed and the health physics personnel (and equipment) are made available in a consultative capacity, but any emergency decisions regarding water use, evacuation, etc., are made by state agencies. This division probably makes good sense in law, but may require some review to ensure adequate effectiveness for any protective measures or to ensure rapid determination of contamination levels. It may be desirable to incorporate the provision of services in emergencies whenever a surveillance program is being drawn up.

Section 3

RADIOANALYTICAL OPERATIONS

Since there are two components to the cost of operating an environmental surveillance program, sampling and analysis, it seemed worth examining the analytical operations in more detail to determine, what are the relations between laboratory functions and overall cost and to what extent would costs be affected by the reduction or elimination of survey items that might be judged to be of little value or significance in terms of safeguarding the public or alerting the plant operator against the consequences of any unanticipated radioactive releases. This examination becomes important in any attempt to segregate those functions that effectively monitor or can monitor plant operations from those that may be regarded to serve mainly a public-relations or public re-assurance purpose.

Although a fairly clear picture has emerged through discussions with several major laboratory contractors and EPA laboratories regarding the operation of commercial radioanalytical laboratories, it was decided to set up independent radiochemical and radioassay facilities whose operations could be tested without interfering with ongoing routine assay work. Information was desired from this work on the following parameters:

- the time and effort required for radiochemical separation of water, milk and vegetation samples
- the statistical accuracy available in representative counting systems for samples of typical size under commercial limitations on equipment availability
- the relationship between cost per sample and radioactive content at different levels of required precision and accuracy
- the cost trade-off within a given budget between numbers of samples for iodine, cesium and strontium analyses
- the added cost entailed by adding Sr-89 to existing Sr-90 analysis requirements
- the feasibility of cutting analytical costs by deriving Sr-90 concentrations from Cs-137 determinations

- the step-wise cost factors related to maximum work load per analyst or per counting system
- cost relationships between work done in-house by the utility or under contract outside

The laboratory work was confined to determinations of iodine, strontium and cesium in environmental samples, since they account for the bulk of the assay work. At a later stage it may be desirable to consider tritium analyses in the same context. Gross beta and gamma analyses were not considered as they constitute mainly a screening function and gross-gamma measurements are superseded increasingly by qualitative and quantitative gamma-ray spectrometry.

Iodine determinations received the greatest attention because they constitute a major portion of the analytical work load, and they are regarded as the critical nuclide (14). Consequently specifications call for iodine determinations at the 0.5 pCi/ℓ concentration level, far lower than requirements for other radionuclides. At such levels cost-effectiveness considerations become significant, both in terms of readily attainable accuracies and of capacity of equipment available to count a reasonable number of samples in a reasonable time. This aspect was explored most thoroughly, as it does not seem to have received much consideration previously and has a strong bearing on the usefulness and cost-effectiveness of alternative surveillance programs.

LABORATORY STUDIES

Radiochemistry

1. Iodine. Extraction procedures for iodine followed the usual current procedure (11,14,15) consisting of ion exchange extraction, NaOCl elution, reduction, and precipitation as palladous iodide. The detailed procedure and equipment are described in HASL-300 (11). No particular problems were encountered, but the consistency of results varied appreciably; as so often this probably depends on the experience of the analyst.

The time per extraction is essentially independent of iodine content, since the quantity precipitated is mainly composed of carrier material.

Precipitates are counted initially, to check extraction yield, by means of a low-level beta detector. After correcting of self-absorption in the filter the counting efficiency was found to be 50.3% ± 1.8%. Iodine samples were extracted from water and milk samples with comparable extraction yield. In milk the stable iodine content must also be determined.

2. Strontium. Strontium analyses were conducted using mainly HASL methods. Using Sr-85 as a tracer, yields of the order of 80% were obtained from tap water and rainwater, and lower yields from grass and soil samples. Vegetation was dry-ashed before addition of strontium carrier; for water samples Sr carrier was added before evaporation and ashing. For determination of Sr-90 repeated fuming nitric acid separations are used to remove calcium and alkaline earths. Barium chromate is used to remove traces of Ra, Pb, Ba and various fission products. After time for equilibration of the yttrium-90 daughter of Sr-90, the yttrium is precipitated as the hydroxide and converted to the oxalate for counting. Strontium and yttrium carriers were standardized in triplicate. After correction for self-absorption, counting efficiency for Y-90 in the Beckman Low Beta counter was found to be 45.5%.

A series of spiked water samples was assayed for statistical evaluation of reproducibility. Half of the samples used Sr-85 tracer for yield determination, half gravimetric yield. The tracer method was found to be more rapid and to result in substantially higher strontium recovery. The consistency was only of the order of ± 20%, but with small samples most of this error was traced back to pipetting errors.

3. Cesium. The initial steps for cesium extraction are similar to those for strontium and some saving in proportionate manpower could be obtained by doing parallel analyses on both elements from the samples. The major cost factor in cesium extraction is for chloroplatinic acid, which accounts for a cost of the order of $12 per determination.

Cesium determinations were done on spiked synthetic samples and on check samples received from the Environmental Protection Agency. The results were also plotted to show statistical accuracies obtainable and to develop cost data for the separation work.

4. Sr-Cs Ratios. As a possible means of reducing analytical costs it has been proposed at various times to assume a constant ratio of strontium to cesium in air and water and to deduce Sr-90 concentrations from the more abundant cesium-137 values.

Table 3-1 shows the concentrations of Sr-90 and Cs-137 in effluents from all of the large BWR and PWR nuclear power stations in the U.S. that operated in 1974, based on a draft summary by the NRC for that year -- the most recent one for which data are available. An initial examination of the data suggests that the range of the individual radionuclides in both airborne and liquid effluents is too large and fluctuating to expect any consistency in the pattern of ratios. It is conceivable that a pattern could be seen if the following extreme values were explained away:

- Pilgrim-1 -- Sr-90 in airborne effluent relatively low
- Browns Ferry-1 -- Sr-90 in airborne effluent relatively low
- Ft. Calhoun -- Sr-90 in airborne effluent relatively high
- Turkey Point-3,4 -- Cs-137 in airborne effluent relatively high
- Millstone-1 -- Sr-90 and Cs-137 in liquid effluent relatively high
- Browns Ferry-1 -- Cs-137 in liquid effluent relatively low

Concerning the Sr-90/Cs-137 ratio, the only one that seems even reasonably consistent is at BWR's for liquid effluents where the range (omitting the Browns Ferry-1 value) is 0.0017 - 0.0211. Possibly with more data and more of the stations having operated for several years, a pattern will emerge. At present, one should be cautious in accepting all of the data at face value because of the possibility of analytical problems or incomplete reporting of all effluents. In that respect, one would expect the liquid discharge analyses to be more reliable.

Table 3-2 gives the same values by month for the year 1975 at the Dresden-2,3 stations, except that the airborne discharges are given separately for two discharge points. The ratios vary by almost two orders of magnitude throughout the year. The sensitivity of analysis may have changed between semiannual reports, as indicated by what appear to be rounded-off values for Sr-90 in air during the first six months. As for the data in Table 3-1, any use of the average or extreme ratio should be preceded by a careful consideration of the sampling locations that yield the data, the analytical

Table 3-1

RELATION OF ^{90}Sr TO ^{137}Cs DISCHARGES AT U.S. NUCLEAR POWER STATIONS IN 1974

Station	Airborne Discharge, Ci			Liquid Discharge, Ci		
	^{90}Sr	^{137}Cs	^{90}Sr/Cs^{137}	^{40}Sr	^{137}Cs	^{90}Sr/Cs^{137}
BWR						
Oyster Creek	1.2×10^{-3}	2.6×10^{-3}	0.46	6.0×10^{-3}	NA	-
Millstone-1	4.0×10^{-4}	3.7×10^{-3}	0.11	2.0×10^{0}	9.5×10^{1}	0.0211
Nine Mile Pt-1	4.6×10^{-3}	NA	-	1.2×10^{-1}	9.8×10^{0}	0.0122
Dresden-2,3	9.0×10^{-3}	1.0×10^{-2}	0.90	2.8×10^{-2}	6.8×10^{0}	0.0041
Monticello	0	0	-	0	0	-
Pilgrim-1	5.2×10^{-6}	4.4×10^{-4}	0.013	2.7×10^{-3}	1.6×10^{0}	0.0017
Quad Cities-1,2	9.5×10^{-5}	NA	-	4.5×10^{-2}	6.0×10^{0}	0.0075
Vermont Yankee	NA	7.8×10^{-4}	-	0	0	-
Browns Ferry-1	2.6×10^{-5}	1.9×10^{-3}	0.014	2.6×10^{-3}	5.3×10^{-3}	0.49
Range	9.0×10^{-3} to 5.2×10^{-6}	1.0×10^{-2} to 4.4×10^{-4}	0.90 to 0.013	2.0×10^{0} to 2.6×10^{-3}	9.5×10^{1} to 5.3×10^{-3}	0.49 to 0.0017
PWR						
Indian Point-2	2.7×10^{-4}	5.3×10^{-4}	0.51	2.6×10^{-4}	2.4×10^{-1}	0.0011
Zion-1	3.4×10^{-5}	4.0×10^{-5}	0.85	0	0	-
Ft. Calhoun	4.2×10^{0}	NA	-	7.0×10^{-5}	NA	-
Oconee-1	NA	3.2×10^{-5}	-	1.6×10^{-3}	5.9×10^{-2}	0.0271
Turkey Point-3,4	1.2×10^{-5}	8.8×10^{-2}	0.00014	1.9×10^{-4}	6.7×10^{-2}	0.0028
Palisades	NA	NA	-	NA	1.5×10^{0}	-
Connecticut Yankee	NA	NA	-	9.1×10^{-4}	2.7×10^{-1}	0.0034

Table 3-1 (Continued)

Station	Airborne Discharge, Ci			Liquid Discharge, Ci		
	^{90}Sr	^{137}Cs	$^{90}Sr/Cs^{137}$	^{40}Sr	^{137}Cs	$^{90}Sr/Cs^{137}$
PWR						
R. E. Ginna-1	NA	2.0×10^{-5}	-	NA	3.9×10^{-2}	-
Maine Yankee	NA	3.5×10^{-5}	-	1.4×10^{-5}	9.3×10^{-1}	0.000015
Point Beach-1	NA	2.3×10^{-4}	-	1.5×10^{-4}	9.8×10^{-2}	0.0015
Surry-1,2	NA	1.7×10^{-3}	-	1.5×10^{-3}	6.8×10^{0}	0.00022
San Onofre	NR	NR	-	NR	NR	-
H. B. Robinson-1	NA	NA	-	1.1×10^{-3}	2.0×10^{-1}	0.0055
Range	4.2×10^{0} to 1.2×10^{-5}	8.8×10^{-2} to 2.0×10^{-5}	0.85 to 0.00014	1.6×10^{-3} to 1.4×10^{-5}	6.8×10^{0} to 3.9×10^{-2}	0.027 to 0.000015

Notes: NA: Not analyzed (inferred from zero values for ^{90}Sr and/or ^{137}Cs when values are reported for other radionuclides)

NR: Not reported (no information given for this station)

Data from draft NRC summary (B. Weiss, personal communication)(21)

Table 3-2

RELATION OF ^{90}Sr TO ^{137}Cs DISCHARGES AT DRESDEN-2,3 NUCLEAR POWER STATION IN 1975 BY MONTH

Month	Airborne discharges at chimney, Ci			Airborne discharges at vent stack, Ci			Liquid discharges, Ci		
	^{90}Sr	^{137}Ci	$^{90}Sr/^{137}Cs$	^{90}Sr	^{137}Cs	$^{90}Sr/^{137}Cs$	^{90}Sr	^{137}Cs	$^{90}Sr/^{137}Cs$
Jan.	4.0×10^{-4}	1.0×10^{-4}	4.0	3.0×10^{-4}	1.7×10^{-3}	0.176	0	0	-
Feb.	4.0×10^{-4}	2.2×10^{-3}	1.82	3.0×10^{-4}	2.1×10^{-3}	0.143	1.9×10^{-5}	4.7×10^{-4}	0.021
Mar.	8.0×10^{-4}	3.7×10^{-3}	0.22	5.0×10^{-4}	4.5×10^{-3}	0.111	2.0×10^{-4}	1.3×10^{-2}	0.015
April	6.0×10^{-4}	6.3×10^{-3}	0.095	5.0×10^{-4}	8.0×10^{-4}	0.62	1.0×10^{-3}	6.9×10^{-3}	0.145
May	5.0×10^{-4}	ND	-	4.0×10^{-4}	7.4×10^{-3}	0.054	4.1×10^{-3}	NR	-
June	1.0×10^{-4}	1.3×10^{-3}	0.077	2.0×10^{-4}	5.3×10^{-3}	0.038	2.6×10^{-3}	NR	-
July	1.1×10^{-4}	NR	-	1.8×10^{-5}	3.4×10^{-4}	0.053	1.5×10^{-4}	NR	-
Aug.	1.5×10^{-4}	NR	-	4.4×10^{-5}	1.6×10^{-4}	0.28	1.1×10^{-4}	NR	-
Sept.	1.7×10^{-4}	3.0×10^{-3}	0.057	5.9×10^{-5}	4.5×10^{-4}	0.131	2.2×10^{-4}	NR	-
Oct.	5.2×10^{-4}	4.1×10^{-3}	0.127	6.2×10^{-5}	2.6×10^{-3}	0.024	7.0×10^{-5}	1.5×10^{-2}	0.0047
Nov.	4.8×10^{-4}	5.2×10^{-3}	0.092	3.3×10^{-5}	1.2×10^{-3}	0.028	NR	NR	-
Dec.	2.1×10^{-4}	1.0×10^{-3}	0.21	4.7×10^{-4}	3.9×10^{-3}	0.121	1.0×10^{-5}	5.3×10^{-4}	0.019
Range	8.0×10^{-4}-	6.3×10^{-3}-	4.0-	5.0×10^{-4} -	5.3×10^{-3} -	0.62-	4.1×10^{-3}-	1.5×10^{-2}-	0.145-
	1.0×10^{-4}	1.0×10^{-4}	0.057	1.8×10^{-5}	1.6×10^{-4}	0.024	1.0×10^{-5}	4.7×10^{-4}	0.0047

NR = Not reported

ND = Not detected

Data from Dresden Nuclear Power Station Semiannual Reports procedures and the plant operation at the time. At the moment, it appears that the use of cesium values to deduce strontium concentrations in order to reduce analytical costs is not possible and could be highly misleading.

Counting Procedures

The main purpose of setting up counting facilities was to test the statistical limits placed on attainable accuracies when counting times are not unlimited. For iodine the beta-gamma coincidence technique of Paperiello and Matuszek (16) was adopted as providing a theoretical possibility of measuring iodine in milk or water at concentrations down to 0.05 pCi per liter. The detector consists of a thin plastic scintillator held close to the filter disk containing the palladium iodide precipitate. This is viewed by a one-inch diameter photomultiplier. This is placed above a 5 x 5 inch diameter NaI(Tl) scintillation detector, which counts the gamma-ray emission. The counting system and methods of error analysis are described in detail in Appendix A.

The probable error in the net countrate was computed for a sample containing various amounts of activity, counted for various times, with different backgrounds, background count times, and detector (coincidence) efficiencies.

A FORTRAN program was written to allow a large number of combinations of the parameter values to be used to calculate the relative error. One objective was to see what activity could be detected with a 5% relative error (at 1σ, in net cpm) with a two-hour count (a reasonable commercial time). For 10% efficiency and 0-10 cpm background this activity is 15 pCi. (A lower background would reduce this only slightly. For 5% relative error, one needs to count 5 pCi for six hours even with 0.005 cpm background.)

One way of presenting this information is graphically, as in Figures 3-1 and 3-2. These show (1) the relative error in net counts (cpm) associated with various amounts of I-131 activity, for various counting times, for a given background and efficiency; (2) the approximate activity required to obtain an ~ 5% relative error as a function of efficiency for two- and three-hour sample counts. Note that the background for Figure 3-1 is 0.05 cpm while that for Figure 3-2 is 0.10 cpm. This is an artifact of the way in which the computer runs were obtained, and does not obviate comparisons between

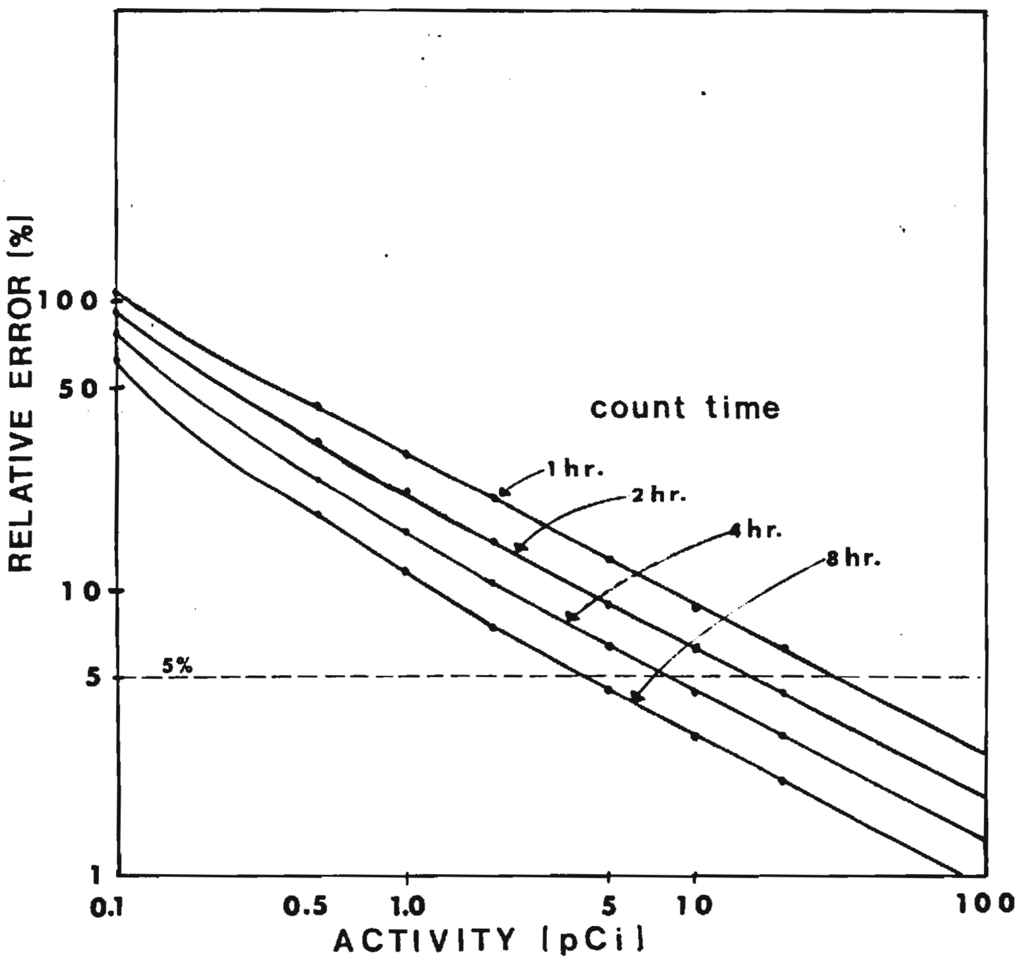

Figure 3-1. Relation Between Probable Error and Sample Activity for Various Counting Times (I-131 Samples)

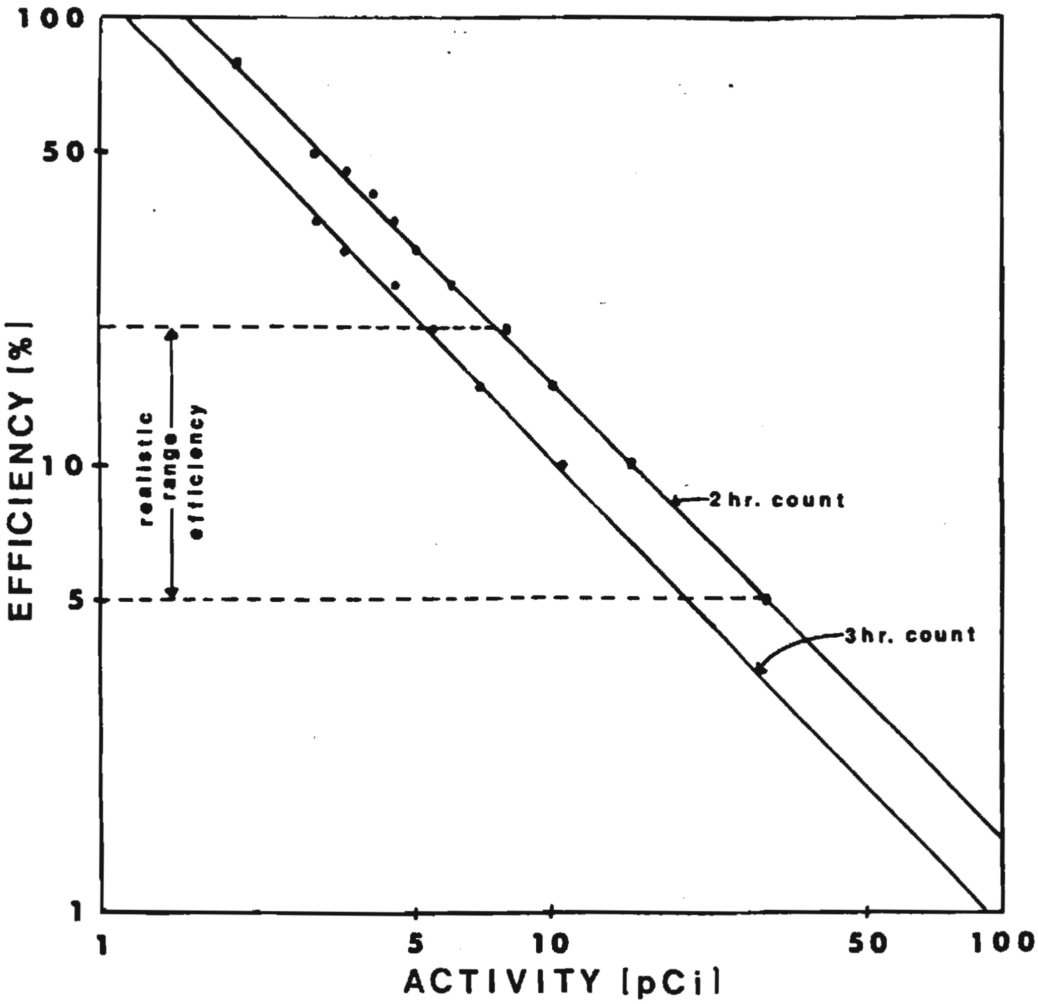

Figure 3-2. Effect of Detector Efficiency on Required Counting Times to Obtain 5% Accuracy for Various I-131 Sample Activities

the two curves. (The computer data can be arranged in many other possible ways, or can be easily re-run to cover parameter ranges of interest.)

Similar detectability curves have been obtained for cesium-137 samples using a sodium iodide scintillation detector and are shown in Figure 3-3.

Since the counting error is proportional to the inverse square root of the total number of counts, a high-level sample can be counted to any desired degree of accuracy by counting long enough, if we ignore for the moment the contribution of systematic errors and drift effects. For the low levels of activity encountered in most environmental samples the situation is rather different. In practice the sample volume for milk or water samples is of the order of 1-4 liters. The example quoted in Regulatory Guide 4.3 (14) of detecting an iodine-131 concentration of 0.5 pCi/ℓ with a standard deviation of ±7% presupposes a counting time of 1000 minutes, not including the time for obtaining the background count. Such a long counting time, about one sample per day, is excessively expensive in any commercial operation and would entail a severe limitation on the number of samples that could be handled.

If one accepts an upper cost limit in terms of counting time available and manpower commitments, one arrives at certain minimum concentrations, at any given level of accuracy, that can reasonably be handled commercially without incurring excessive sample costs. These considerations then have a bearing on the analytical accuracy that should be prescribed in Tech Specs or Regulatory Guidelines and militate against a further lowering in concentrations in environmental samples that must be reported, unless it can be shown that the sample is of sufficient importance in safeguarding the public to justify the extra expense.

Figure 3-4 shows the relationship between counting time and sample activity for the iodine detection system. It is evident that a two-hour counting time limit would make it impossible for this system to assay any sample containing less than 10 pCi with a probable error as low as 5%, and even for a 10% error there would be a lower limit of 4 pCi per sample, assuming that non-statistical sources of error can be neglected. These curves would be shifted slightly for different detector efficiencies.

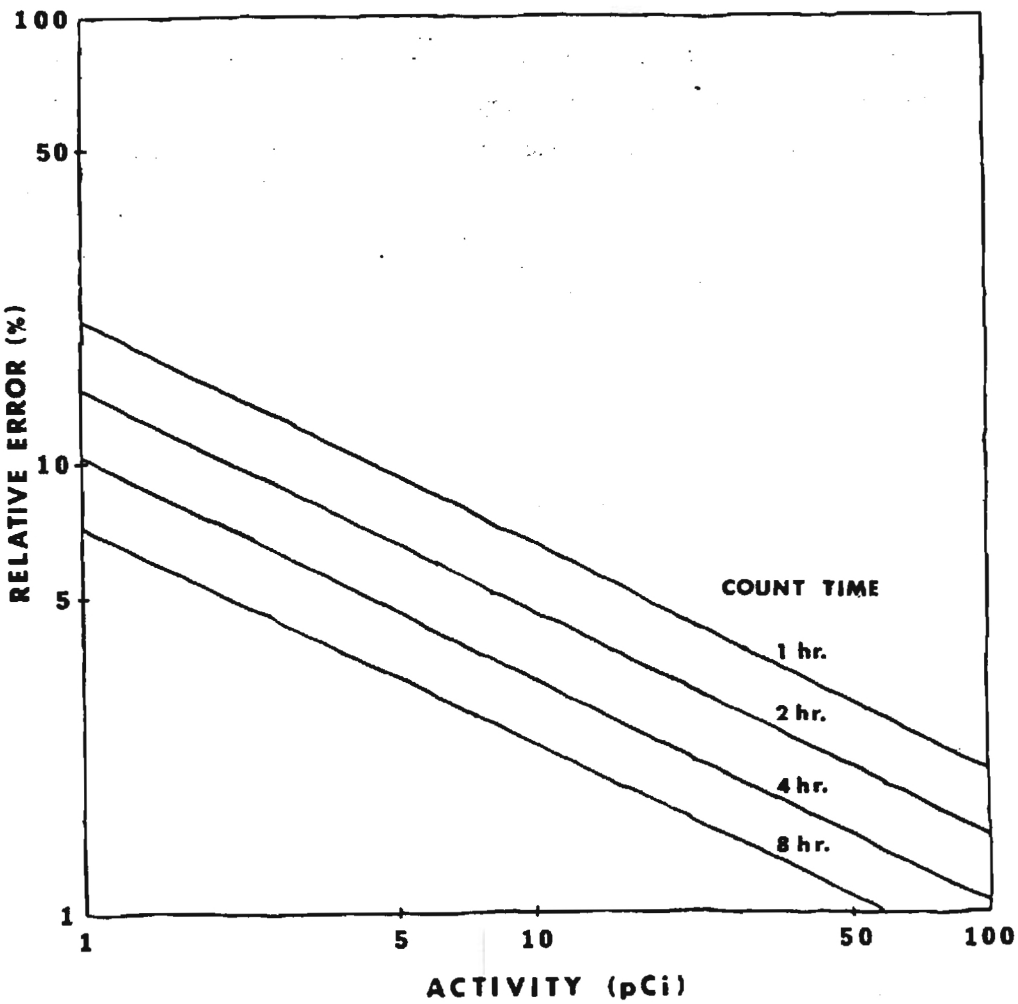

Figure 3-3. Attainable Accuracy in Cs-137 Samples for Various Counting Times

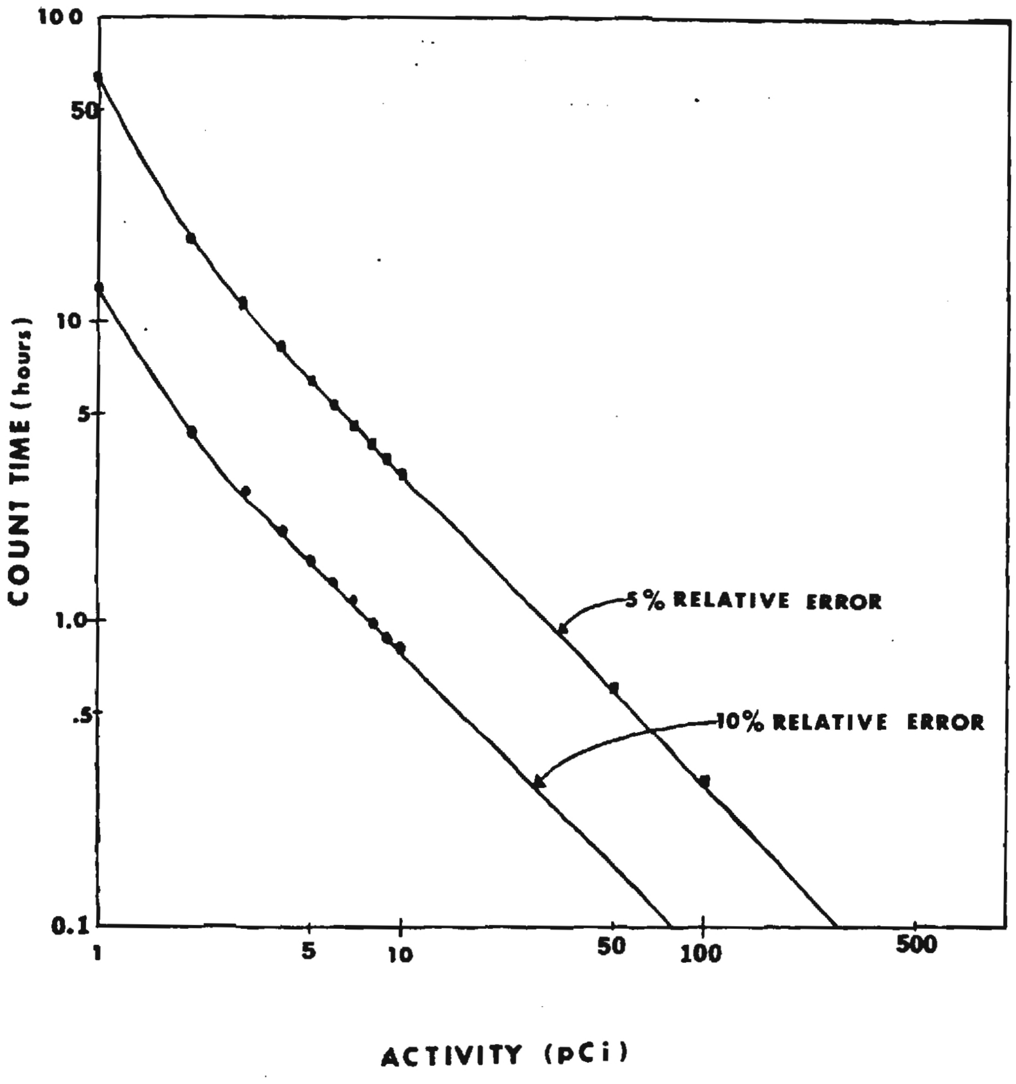

Figure 3-4. Minimum Counting Times for a Given Accuracy for I-131 Sample

COST CONSIDERATIONS

To evaluate the cost of analysis for a given sample one has to consider the sum of the costs for sample collection, radiochemical concentration and counting for each radionuclide and for each type of sample material. As Figures 3-2 through 3-4 have shown there are practical limits on the detectability of certain levels of activity governed by the availability of equipment and manpower. For the three radionuclides of interest the extraction cost is essentially independent of activity concentration, whereas the counting cost depends on the required counting time; even there, there is a minimum handling time per sample for sample changing, record keeping, etc., below which the laboratory time cannot be reduced in practice.

To estimate the total cost per sample, we have considered the cost and precision of the chemical separation to be constant regardless of activity. One can then obtain curves such as those shown in Figure 3-5 which relate the cost of radioassays for iodine-131 in milk or water to the expected sample activity for two different probable-error values. It is seen that for concentrations and activities close to background the cost rises significantly. Yet it may be argued that 10 pCi on a filter sample, derived from a 4 liter milk sample, represents 3 pCi per liter of milk and potentially a radiation dose commitment of 15 mrem/yr. This is certainly still quite high, and it may justify the extra cost entailed in analyzing down to an equivalent dose of the order of 1 mrem/yr or one may have to accept a lower assay precision.

The cost per sample shown in Figure 3-5 is estimated on the basis of an assumed cost of $30 per sample for chemistry and other fixed costs, at either $1.33 or $3.00 per hour of counting time. The 1σ relative error curves include errors of 5% on yield (based on six replicate samples), 5% on efficiency and 5 and 10% on net count rate.

For a sample activity of 1 pCi, the cost per sample is in the range of about $50-70 at 12.3% error, under the above assumptions. For a 4-liter milk sample, 1 pCi corresponds to a potential dose of 1.5 ± 0.2 mrem/yr. A relatively small decrease in error, to ± 0.13 mrem/yr, could be achieved at a rise in cost to $100-200 per sample, i.e. a doubling in cost for a minor improvement in the significance of the measurement.

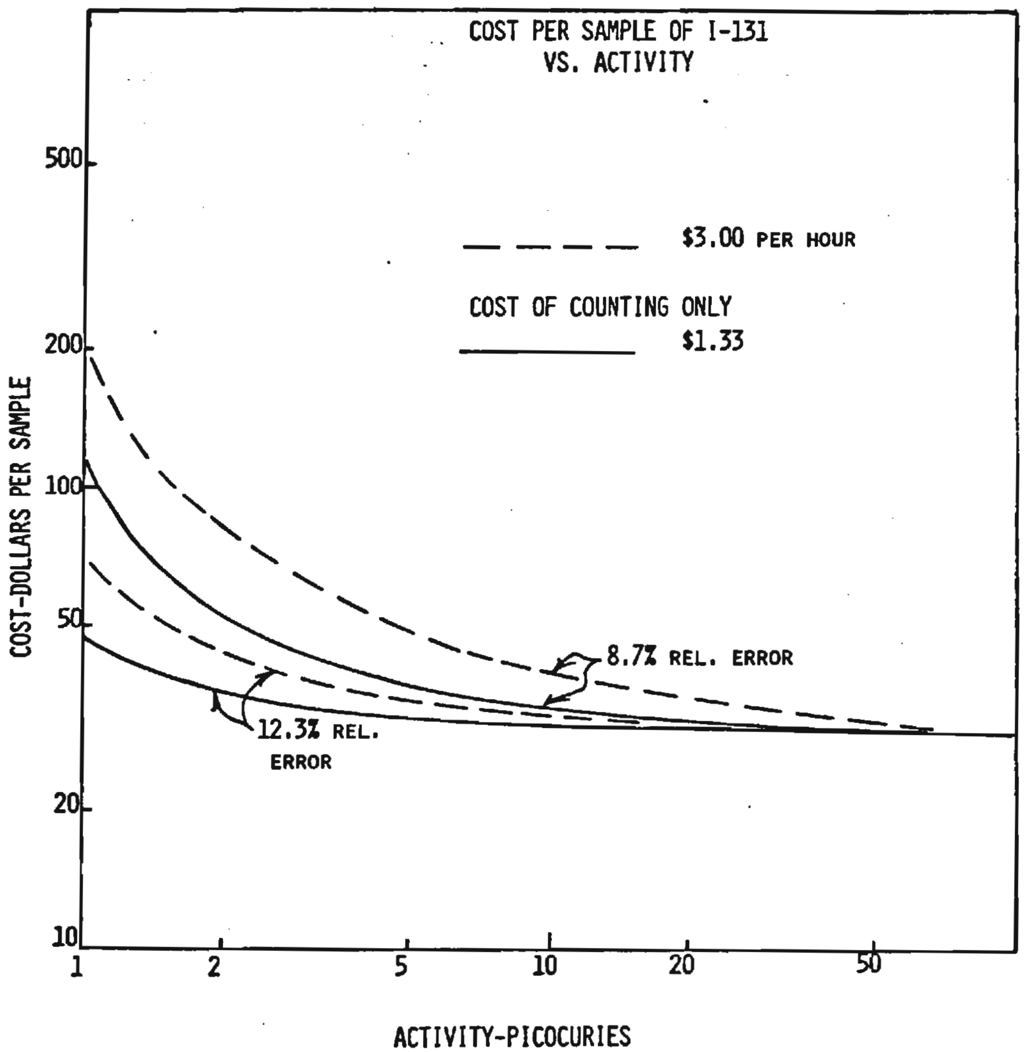

Figure 3-5. Assay Cost for Iodine Determination for Various Sample Activities for Two Levels of Accuracy

The above hourly cost figures are probably low as they do not provide for amortization of equipment or overhead. A typical gamma-ray spectrometer and beta-gamma coincidence system would cost about $25-30,000, or about $9,000 per year for a three-year write-off time. For a maximum operating time of 2000 hr/yr, excluding background counts, this would contribute a cost of $4.50/hr. Labor costs would be of the order of $6.50/hr prorated; therefore, with 25% for supervision and services the cost before profit and overhead more realistically would be of the order of $14 per hour. If this equipment is used to run four samples, for two hours each, per day its weekly capacity would be only 20 samples at $28/sample. To this one would then have to add the cost of chemical separation.

Because of the limited equipment capacity for low-level samples, it pays to run enough samples to fully utilize the equipment, but beyond the limiting number, equipment costs jump to the next complete unit. It is for this reason that some savings can be achieved by screening samples by means of gross beta or gamma counts, thus eliminating null samples of lesser significance from more detailed attention. There is an inherent discrepancy in the optimum sample load that can be handled by a technician in a chemical laboratory or in a counting lab; this arises from the fact that several samples can be prepared simultaneously, but counting must be done sequentially. For this reason most contractors prefer discussing anticipated sample numbers before quoting costs.

Table 3-3 lists estimates for required analytical times per sample kindly supplied by one government laboratory (Dr. J. Harley of HASL) and one private organization (S. Waligora of Eberline Instruments). It is evident that the time per sample, and hence the cost, is lower if an ideal number can be treated at the same time. The estimates for the two organizations are seen to be comparable, except for plutonium analyses where it is assumed that the HASL procedures provide for counting to a significantly lower concentration level.

Table 3-3

ESTIMATED ANALYSIS TIMES FOR ENVIRONMENTAL SAMPLES

A. HASL Estimates

Food and Deposition

Sr-90 - 3 hr/sample in batches of 18 - ~750 Analyses/Man-Year

Cs-137 - 3 hr/sample in batches of 18 - ~750 Analyses/Man-Year

Sr-89 - 1.3 hr/sample in batches of 18 when Sr-90 is Analyzed

Pu-239,240 - 27 hr/food sample in batches of 6 - ~80 Analyses/Man-Year
33 hr/deposition sample in batches of 6 - ~65 Analyses/Man-Year

Soil

Sr-90 - 4 hr/sample in batches of 18 - ~520 Analyses/Man-Year

Cs-137 - 4 hr/sample in batches of 18 - ~520 Analyses/Man-Year

Sr-89 - 1.3 hr/sample in batches of 18 when Sr-90 is Analyzed

Pu-239,240 - 27 hr/sample in batches of 6 - ~80 Analyses/Man-Year

B. Eberline Estimates

	Time per sample (batch)	Time per sample (single)
Gamma-ray spectra in food, milk, vegetation	2.5 hr	4 hr
Sr-89/90 in food, milk, water, air filters	3	4
Sr-89/90 in soil	3	4.5
I-131 in milk (low level)	2.5	3
H-3 directly	0.8	1.2
H-3, electrolytic concentration	2.5	3
Gross alpha or beta on air filters	0.3	0.5
Gross alpha or beta in water	0.4	0.9
Pu-239/240 in food, vegetation, air filters	2	3
Pu-239/240 in meat, fish	2.5	3.5
Pu-239/240 in soil	5	8

Section 4

DESIGN AND SELECTION CRITERIA FOR SURVEILLANCE PROGRAMS

In discussing the design of surveillance programs one has to recognize the impact and the boundaries imposed by present legal requirements. Some of the existing laws and regulations are reviewed in Appendix B, by W. C. Evans. Other portions of the programs have evolved by gradual accretion from previous programs with some phased reductions under action-level approaches. Basing survey programs on the critical-pathway approach, which is preferred by many experts in the field, has not found acceptance by the Nuclear Regulatory Commission, a reversal that is recognizable in the difference between the draft and final versions of Regulatory Guides 4.1 and 4.8 (8-10).

Within these frameworks it is legitimate to ask whether a given program component is necessary, is effective, provides useful and meaningful information, is worth the cost, or backs up certain legal or regulatory aspects of plant operations. There may also be a valid question, if its data can provide unequivocally a direct relationship between observed environmental changes and any given feature of plant operations, and whether the program is useful as a contribution to knowledge or for maintaining good public relations with the neighboring community.

To optimize the program in order of increasing "usefulness," one can evaluate a utility function U_j for each program component j, which expresses the desirability of a particular alternative. The utility function can be expressed as

$$U_j = P_1 \cdot u_{j1} + P_2 \cdot u_{j2} + P_3 u_{j3}$$

where u is the attribute value, and P is a preference index subject to $0 < P_j < 1$, and $\Sigma P_j = 1$ where the preference values reflect an agreed weighting for the various categories in this evaluation. Table 4-1 lists some of the selection criteria and some possible weighting factors. Not all of the criteria listed are independent of each other.

Table 4-1

SELECTION CRITERIA FOR SURVEY COMPONENTS

Criterion Number	Selection Criterion	Weighting Factor
1	Regulatory requirement	3
2	Safety back-up to effluent monitors	2
3	Effectiveness	3
4	Meaningful data	2
5	Low cost of sample collection	2
6	Low cost of analysis	3
7	Low manpower requirement	1
8	Compatible with emergency procedures	1
9	Independence from operator bias	2
10	Protection of public	3
11	Direct indication of impact	2
12	Rapid indication of impact	2
13	Good public relations	1
14	Training value	1
15	High reliability	2
16	Uniqueness of information	2
17	Back-up records for potential litigation	1
18	Creates employment	1
19	Research support	1
20	Permits reduction in exclusion zone area	2
21	Supports operational economics	2
22	Verifies water purity	1
23	Verifies absence of air pollution	1
24	Low cost of data handling	2

Another approach is to assign evaluation points to each program component, as shown in Table 4-2, for a hypothetical program. In that case each component is given a weighting factor W on a scale from 1 (least important) to 3 (highly important) and a quality rating R on a scale from 1 (very poor) to 5 (very good), based on need, usefulness or effectiveness of that particular item. The main value of such an evaluation lies not in the final point rating so much as in the need to examine critically each portion of the survey program for its usefulness and meaningfulness.

If we assign greatest weight to those measurements that represent a critical pathway or the highest contribution to the estimated population dose, as well as those necessary for the enforcement of legal ceiling levels, e.g. ΔT, each plant will end up with a small number of measurements that constitute the irreducible minimum under Action Level 1 conditions (no high-release incidents over a protracted period). These include typically the following:

a) TLD measurements of airborne activity around the plant site, out to five miles;

b) Iodine and strontium-90 determination in composite milk samples from commercial dairy herds within 5 miles, where applicable;

c) Analysis of gross gamma emitters in marine organisms of commercial significance, where applicable;

d) Analysis of drinking water at intake points to downstream municipal treatment plants, and selected wells within 10 miles, as appropriate, including tritium analyses;

e) Fixed-point temperature recording in receiving streams at two or three points above and below the plant; and,

f) Particulate filter samples near the fence line, for iodine determinations and others as needed.

Table 4-3 shows a representative surveillance program based on such considerations. Obviously, for every plant a different determination must be made regarding the pathways representing the major population-dose contribution.

A second form of program evaluation is based on a cost assessment of all components. The question may be asked: given a limited budget for surveillance programs, what is the most useful and cost-effective way of distributing

Table 4-2

OPERATIONAL PROGRAM EVALUATION, HYPOTHETICAL SURVEILLANCE PROGRAM

	Weighting Factor W	Rating R	Evaluation Points W x R
Radiological Program			
Stream water Cs, Sr	3	5	15
Water gross beta	2	2	4
Well water, gross γ	2	3	6
Cow's milk I	3	4	12
Cow's milk Cs, Sr	2	3	6
Goat's milk	1	2	2
Stream sediments			
γ spectrum	1	3	3
Sr	2	3	6
Fish	2	2	4
Meat samples	1	2	2
Airborne particulates	3	4	12
Precipitation, gross β	1	2	2
" gross γ	1	3	3
Soil	1	3	3
Vegetation, crops	2	3	6
TLD	3	5	15
Ecological Program			
Species census, mammals	1	2	2
" birds	1	2	2
" insects	1	2	1
Fish entrainment	2	3	6
Thermal plume	2	3	6
Aquatic biota, benthic	1	2	2
" algae	3	3	9
" fish	3	4	12
" mollusks	3	4	12
Salinity in soil	1	2	2
Moisture	2	2	4
Total (Program Quality)			159

Exposure Routes or Media & Sample Types	SAMPLING FREQUENCIES AND ANALYSES - by Action Levels, based upon actual emissions as percentages of release rates authorized by 10 CFR 20		
	Action Level 1: Less than 3%	Action Level 2: 3% to 10%	Action Level 3: Greater than 10%
EXTERNAL EXPOSURE TLD Chips	10-20 locations to 5 miles Average mR/day determined by QUARTERLY cumulative exposures: collection and analysis in rotation of 1/3 of all TLDs MONTHLY.		20-30 locations to 10 miles Average mR/day determined by MONTHLY analysis of all TLDs.
ATMOSPHERE Membrane filters for particulates: charcoal cartridges for iodine	Gross beta, every filter, WEEKLY; gamma spectrum of filter and cartridge composites, MONTHLY.	Same as for Level 1, MONTHLY.	Gross alpha and beta, every filter: gamma spectrum of filter and cartridge composites, all WEEKLY.
WATER Potable water	Gross beta, tritium and gamma spectrum analyses: Municipal supplies and nearest off-site wells MONTHLY		plus Sr, 89, 90 analysis MONTHLY
Precipitation	No collection or analyses of precipitation at Level 1 and 2.		Gross beta, tritium and Sr 89 & 90, MONTHLY: gamma spectrum of composite, QUARTERLY.
Surface water & silt (shore locations)	Gross beta, tritium and gamma spectrum, QUARTERLY.	Same as for Level 1, but MONTHLY.	Same as for Level 2, plus Sr 89 & 90 analyses, MONTHLY.
Milk	Tritium, iodine, and Sr 89 & 90 analyses on composite: QUARTERLY, commercial herds only.	MONTHLY during pasture season otherwise QUARTERLY (commercial herds).	Same as for Level 2, but WEEKLY during pasture season, otherwise, MONTHLY (commercial herds to 10 miles & nearest individuals).
AQUATIC BIOTA	Gross beta and gamma spectrum analyses of composites of each category: Commercial fish, molluscs, crustacea. QUARTERLY, as available.	MONTHLY during summer, otherwise QUARTERLY, as available.	Same as for Level 2, plus Sr 89 & 90 analyses.
Water Temperature	2-3 locations, fixed instruments		Same as Level 2, mobile measurements if cooling system broke down or was modified

the budget among the various categories? For example, it may be preferable to accept a lower assay precision for iodine determinations in milk in order to make room for more strontium determinations in stream sediments. Similarly subject to approval of the regulatory authorities it may be desirable to go to a phased action-level plan at an early stage of stable plant operations to concentrate on fewer, but potentially more informative surveillance activities. Among the activities encountered at various plants, it seemed generally agreed among persons interviewed that fish entrainment measurements are among the least cost-effective and triennial soil measurements among the least significant. At each plant one can develop such a list of apparently meaningless operations that may well be reduced in number to save operating costs and paperwork.

The cost and complexity of reporting functions is a not insignificant area of concern at nuclear power plants. As long as the industry is at its present growth stage, much of this may be inevitable and may be needed to provide documentation for future licensing hearings and in case of litigation. However, some problems arise from crowding at reporting dates at specific times in the year, and several times during discussions with plant staff it was suggested that this problem could be alleviated by staggering the reporting dates.

In examining the cost-effectiveness of monitoring a given medium or pathway, we must first establish a criterion for quantitatively measuring "effectiveness." An obvious starting point is to use the estimated dose which would result from a given radionuclide concentration in a medium such as air or water as an indication of the importance of that measurement.

Values for the dose or dose commitment based on a variety of detailed models and codes are available in the literature (19). For air or water, one can simply refer to the RPG or MPC values. Having established the dose rate and associated error in the measurement which is considered significant, this can be expressed in terms of picocuries of activity in a particular sample processed in a given manner. The cost per sample analyzed can be calculated from a knowledge of the laboratory time, materials and equipment required by the method of choice. On this basis one may then establish that the determination of iodine-131 in milk is more important, because it reflects potentially a larger population dose than a measurement, of, say, strontium in tobacco leaves, and hence is more effective in spite of the higher cost of the determination. In the case of the ecological program such "effectiveness" may perhaps be expressed in terms of the fraction of a total universe or population affected.

This judgment on effectiveness then can often be supplemented by the identification of critical pathways and critical population groups and may thus help to avoid dissipating the available manpower and resources on second-order impact events.

A major factor in assessing the cost of a surveillance program is the choice made in assigning responsibility for conducting sampling and evaluation work. It seems fairly clear that it is not cost-effective (particularly if effectiveness is judged in a rather narrow context) for a one or two plant system to develop a complete in-house capability. Larger systems can take advantage of scaling factors which apply both to personnel and instrumentation needs, so that it becomes more attractive to do the analyses within the organization itself. As would be expected from the lack of a clear-cut consensus on this matter, good arguments can be mustered for each approach.

Among the reasons for conducting the entire environmental program within the utility organization one can cite the following:

- Relating environmental concentrations to population and individual doses and to effluent control and monitoring data can be done more thoughtfully and reliably if the gathering and interpretation of these data are not split responsibilities. It is best to keep the important feedback loops as short and direct as possible.
- The variations in environmental radioactivity levels, largely of natural or off-site origin, are such that the long term continuity of the pre- and post-operational data base is extremely important. The quality of the data must be assured over long periods of time (years) and this is under more direct control of the utility if it is generating the data itself.
- In the public relations domain, a well-managed in-house surveillance program would seem to offer more tangible proof of the utility's serious concern about environmental effects than a program based on contract services. In today's climate of cynicism the old argument, that an independent contractor, although paid by the utility, was in the best position to reassure the public, has been diminished.

- Should an accidental release of radioactivity occur, the existence of trained analysts on the staff of the utility rather than in a contractor's laboratory would certainly be an advantage. Faster and more thorough response to the incident should be possible.
- Even if the advantage is only psychological, it would seem that internal audits and quality control programs would inspire greater confidence than audits of a contract laboratory.
- In discussions with regulatory agencies the interpretation and, if needed, the defense of data can be done more effectively by the utility personnel if they have actually been responsible for generating it in the first place.

Among the reasons for having an outside contractor conduct the radiological assay programs are the following:

- With greater volumes of samples handled laboratory personnel can be highly specialized and acquired greater expertise than is available in a company facility.
- The inflow of samples from many sources assures anonymity for any given sample and avoids any conscious or unconscious bias.
- A larger laboratory provides more flexibility in moving personnel to different tasks thus reducing fixed labor costs and, perhaps, lowering the individual assay cost, before overhead.
- Any performance changes will be reflected simultaneously in reports to several customers and can be isolated more easily.
- Central consulting services may be more willing to change procedures as the state of the art advances or obtain more modern equipment than utility facilities operating on a fixed budget.
- The cost of analysis by a contractor is sensitive to control by competition and market conditions
- Suspicion is avoided that reported analyses may have been doctored or selected to make the operator appear in a favorable light.

Thus most or all of the reasons for developing in-house capability can, and undoubtedly will, be countered by vendors offering analytical services to the nuclear power industry. The intent here is simply to point out that there are arguments for either approach and, if cost-effectiveness of the mandatory environmental monitoring program is a concern, the current and future operations of each nuclear utility must be examined carefully. Among the many factors to be considered are:

- present and projected number of separate stations which include nuclear generating plants
- scope of the monitoring program for each--are they essentially duplicates or are there important differences such as might occur in a system which included both river and seaside locations?
- current staff capability and degree of overwork or under-utilization
- existing instrumentation, laboratory facilities and computers
- nature of the accounting system and method of charging off equipment, space, overhead, contract services, etc.
- ultimate planning over a 30-year projected life of the facility

A disturbing feature of more than one program was that the utility personnel responsible for defining the scope of contractor service analyses and for interpreting and using the data were separated from the budgetary aspects and not aware of the costs involved. This situation would be unlikely to produce a cost-effective program.

For a surveillance program following the RG 4.8 recommendations, a typical cost range (in 1975 dollars) for contract services covering all the environmental radioactivity measurements was $50-60,000 per year. Depending on arrangements for related activities such as sample collection, quality assurance, the direct radiation monitoring program, data interpretation and report preparation, the total cost to the utility can easily be twice this much, i.e. well over $100,000 per year per station. The cost per station appears to be relatively constant, regardless of the number of power stations operated by the utility.

In examining the economics of a utility-operated, completely in-house program, one finds that the cost per station decreases markedly as a second and third station are added and then remains almost constant (assuming that the scope of the surveillance program at each station is about the same). In 1975 dollars, the annual cost to the utility when operating three or more nuclear stations was in excess of $100,000/station. The numbers are sensitive to the cost accounting procedures used, especially as regards the cost of space and instrumentation. A typical analysis of costs using a 7-year write-off on major equipment items produced the following allocation:

	fraction of total annual cost
equipment and start-up supplies	30%
lab and office space	10
consumable supplies	4
salaries + 100% overhead	55
maintenance contracts	1

with an average annual cost per station of about $115,000. This is in the same range as the costs for programs relying heavily on contract analytical services. Thus, when faced with the question of whether to place the surveillance program in the hands of a contractor or an in-house laboratory, the particular situation at each utility must be examined in detail.

One area that is closely related to the conduct of the radioassay work is the use and availability of radioactive reference standards for system calibration and cross-industry intercomparisons. In discussion it became evident that the quality, and hence the usefulness, of many of the radioassay data depends on careful calibration of equipment and procedures and on periodic cross checks. Without these one can observe sudden, often unexplained, jumps in reported data, sometimes due to changes in analytical procedures or laboratory personnel. The environmental reference samples prepared by the Las Vegas Laboratory of the U.S. EPA serve a useful function in this respect, but it seems generally agreed that their radioactive content is too high for a valid check on the analysis of low-level environmental samples. Consideration should probably be given to modification of the EPA reference sample program; alternatively other sources for such standards may have to be developed (see also page 2-34).

Lastly, it is becoming increasingly obvious that surveillance programs must mesh in well with any emergency procedures. This calls for some realignment of responsibilities, with perhaps a greater involvement of plant health physics staff in environmental surveillance than is currently the case.

Some reexamination of the legal and technical responsibilities of federal, state and plant-operator staffs for emergency control and monitoring functions should probably be built into any survey program, with a clear distinction between immediate short-term requirements and a potential need for follow-up long-term environmental monitoring.

Section 5

CONCLUSIONS

As this report has shown, it seems timely to review critically the purposes, costs and effectiveness of the various environmental surveillance programs around nuclear power plants. Assuming that the preoperational program has provided baseline data on natural radiation background and pre-existing ecological conditions, there has to be a clear understanding of the objectives and practical limitations of a continuing surveillance program. Certain ecological impacts are inevitable and would accompany the operation of any sizable industrial plant. It is the purpose of the ecological survey program to document these changes and to pinpoint and possibly indicate methods of control for any major unexpected or undesirable ecological changes.

The radiological program cannot be expected to function purely according to cost-effectiveness considerations since many of its components are determined by regulatory requirements or license conditions, and it may be more expedient to continue an operation of recognized limited value than to fight a lengthy bureaucratic battle on a minor issue. Nevertheless, it is time to recognize those program components that do not fulfill an important function or that mainly satisfy a need for good public relations or for contacts with the academic community. Such programs may well be incorporated in plans for future nuclear power plants, but this should be done consciously with a clear identification of such purposes.

For the present it will be useful to review all surveillance programs to see which portions may need reinforcing to ensure that any data obtained are valid and meaningful, which samples could be reduced in number to minimize costs without affecting effectiveness, and which program components can be eliminated as being of minor importance or having little bearing on plant operations. Again, it may be useful to apply a critical pathway approach to simplify any future surveillance programs (18).

In analyzing the cost of survey programs it must be recognized that ordinary economic alternatives are not always available because of the regulatory framework in which the plants operate. However, there still has to be a reasonable relationship between the cost and effort involved in various survey activities and the usefulness of the data obtained (19). It has been shown that the organization of the program has a bearing on its costs and that there are certain scale factors that affect the choice of program parameters.

In the course of this project it has been shown that there are practical, mainly economic, limitations on the number of samples that can be assayed, on the accuracy obtainable in the not unlimited counting time available, and that a deliberate choice may have to be made in selecting the number and required detection level for a limited number of samples that may merit a greater expenditure.

There appears to be a clear need for a centralized quality assurance program to work closely with commercial laboratories, plant operators and government agencies. In that connection it would probably be helpful if the publication of data on fallout and environmental levels that were previously contained in Radiation Data and Reports could be resumed under suitable auspices.

The relationship between existing surveillance programs and emergency monitoring programs may require clarification and possible redefinition in many cases. The initiative for doing so may have to be taken by appropriate state agencies.

In general it is felt that the "action level" approach to phasing out excessive surveillance requirements is a move in the right direction. In the long run it is necessary to save costs and trained manpower by working out a rational survey program with clearly defined purposes to reverse the trend for continuing accretion to such programs. This will require close cooperation between utilities and regulatory agencies based on mutual trust and the involvement of competent people.

The following specific recommendations are submitted:

- Operational phases of an environmental surveillance program should be reviewed critically to identify both important and ineffective components.
- To the extent possible, in the light of each plant's operating history, programs should be adjusted periodically to a less intensive action level.
- Program components that require excessive manpower or expenditures in relation to the value of the data obtained should be eliminated as soon as possible.
- Cooperation between the atomic industry and the regulatory agencies must be developed to reduce unnecessary busy work, and to identify survey activities that serve primarily a scientific research function.
- Provisions should be made, to ease the load on analytical laboratories, to spread the due date for semiannual environmental reports from various stations more evenly over the year.
- Critical pathway analysis should be employed more generally to identify important aspects of the survey programs.
- Steps should be taken to develop a centralized quality assurance program on a cooperative basis to provide analytical verification and to supply environmental reference samples.
- Review existing emergency programs and develop a real-time emergency monitoring system.
- Develop a more standardized format for reporting effluent releases and environmental impact to permit easier intercomparison between different plants.
- Reconsider the information obtained and effort required for collection and analysis of fish entrainment loss samples with the aim of eliminating this program wherever conditions have stabilized.
- Review the usefulness of soil sample programs as currently conducted and drop them until or unless there has been a major release of activity from the plant.
- Apart from temperature monitoring in receiving waters, to provide an independent check on the adherence to coolant water temperature control commitments, and observations on benthic organisms of commercial significance, where applicable, most ecological programs can probably be phased out past the fifth year of routine operation of the power plant.

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Appendix A

COUNTING PROCEDURES

The main purpose of setting up counting facilities was to test the statistical limits placed on attainable accuracies when counting times are not unlimited. For iodine the beta-gamma coincidence technique of Paperiello and Matuszek (16) was adopted as providing a theoretical possibility of measuring iodine in milk or water at concentrations down to 0.05 pCi per liter. The detector consists of a thin plastic scintillator held close to the filter disk containing the palladium iodide precipitate. This is viewed by a one-inch diameter photomultiplier. This is placed above a 5 x 5 inch diameter NaI(Tl) scintillation detector, which counts the gamma-ray emission. Figure 7-1 shows the improved sample holder assembly, Figure 7-2 is a block diagram showing the electronic arrangement for the coincidence counting of the beta- and gamma-ray signals, and Figure 7-3 provides a general view of the equipment.

The system as used had a resolving time of the order of 80 nanoseconds, a detector efficiency of about 10%, and a background rate of 0.05 cpm, mainly due to radon daughters from the wall materials. While the 10% efficiency is not as high as that of some other systems it was considered adequate for the present purpose.

Matuszek and Paperiello (17) have pointed out the importance of non-statistical sources of error. In the present work the two major sources of error of that type were found to be: exposure to light of the photomultiplier tube during sample change; and variation in the sample-detector geometry between samples. Both of these effects were greatly reduced by redesign of the sample holder.

To characterize the behavior of the system, an I-131 source was prepared, and counted several times per day for several weeks. The source was a 9/16 inch diameter filter with PdI_2 deposited, and the filter was mounted on a circular piece of computer card material to provide a firm backing. A small piece of mylar foil was taped over the deposit to keep it in place.

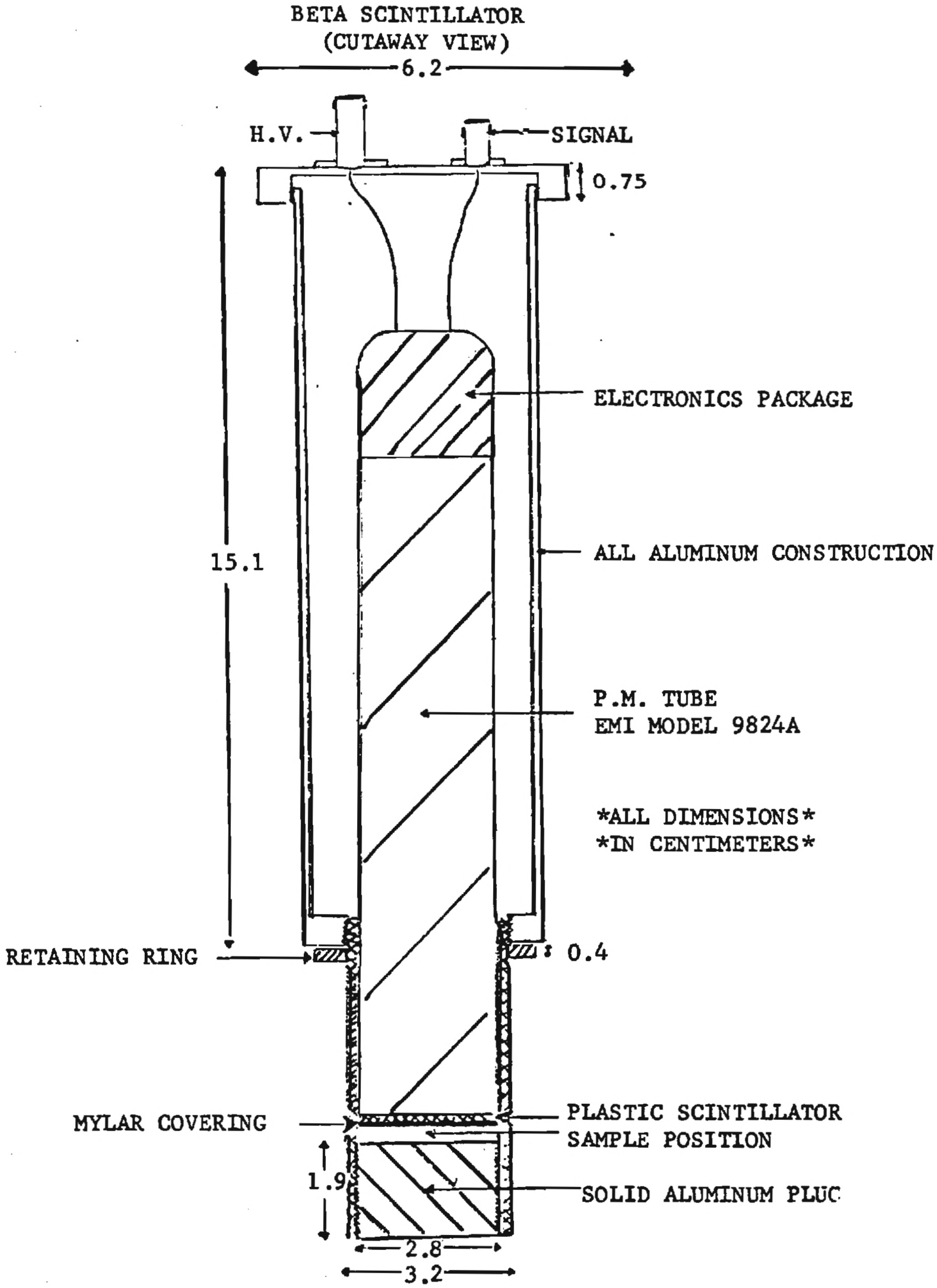

Figure 7-1. Improved Sample Holder of Beta-gamma Coincidence Measurement

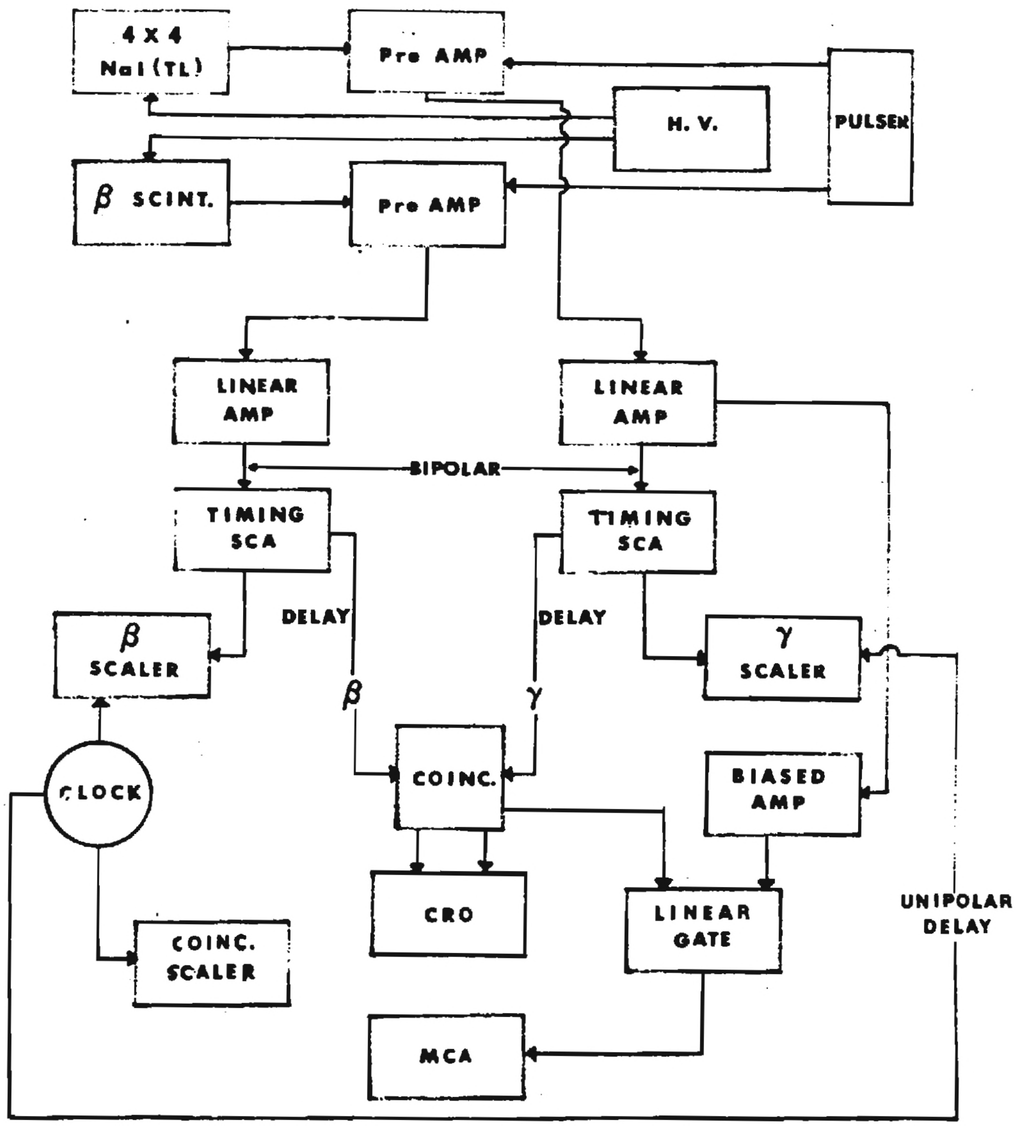

Figure 7-2. Block Diagram of Coincidence System

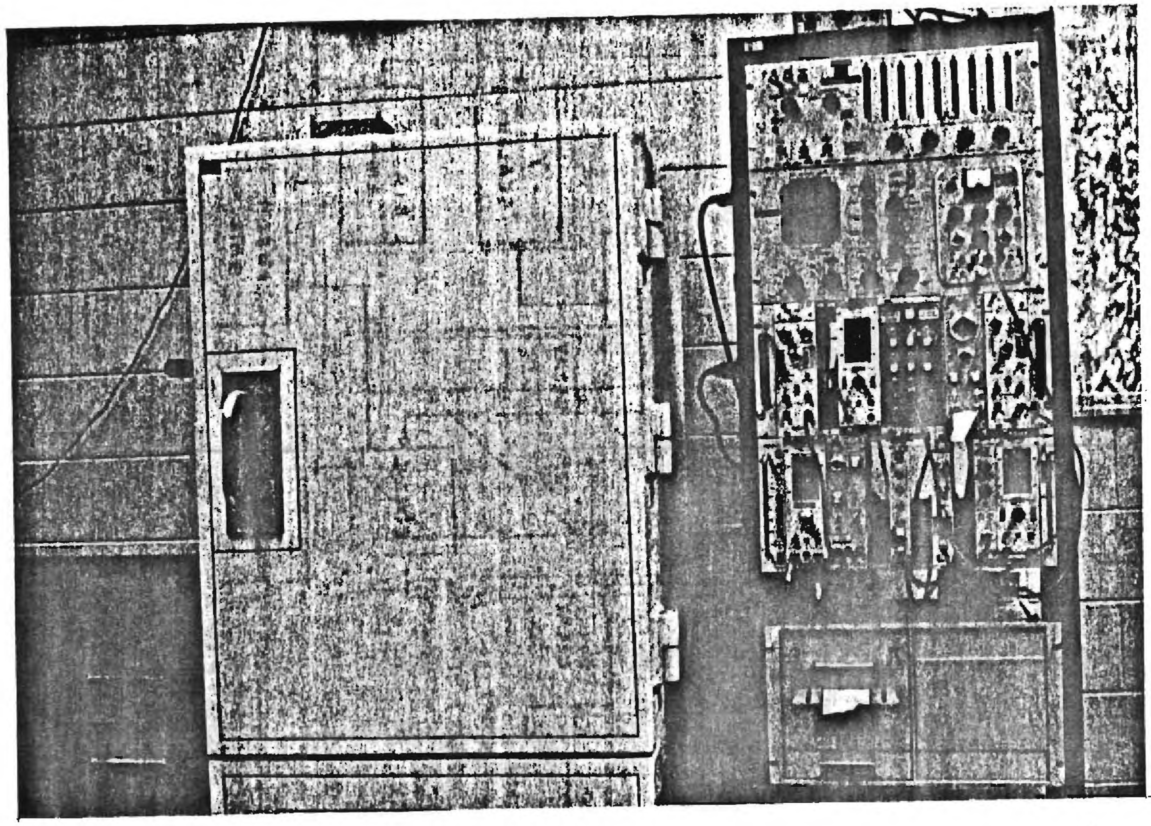

Figure 7-3. View of Beta-gamma Detection System

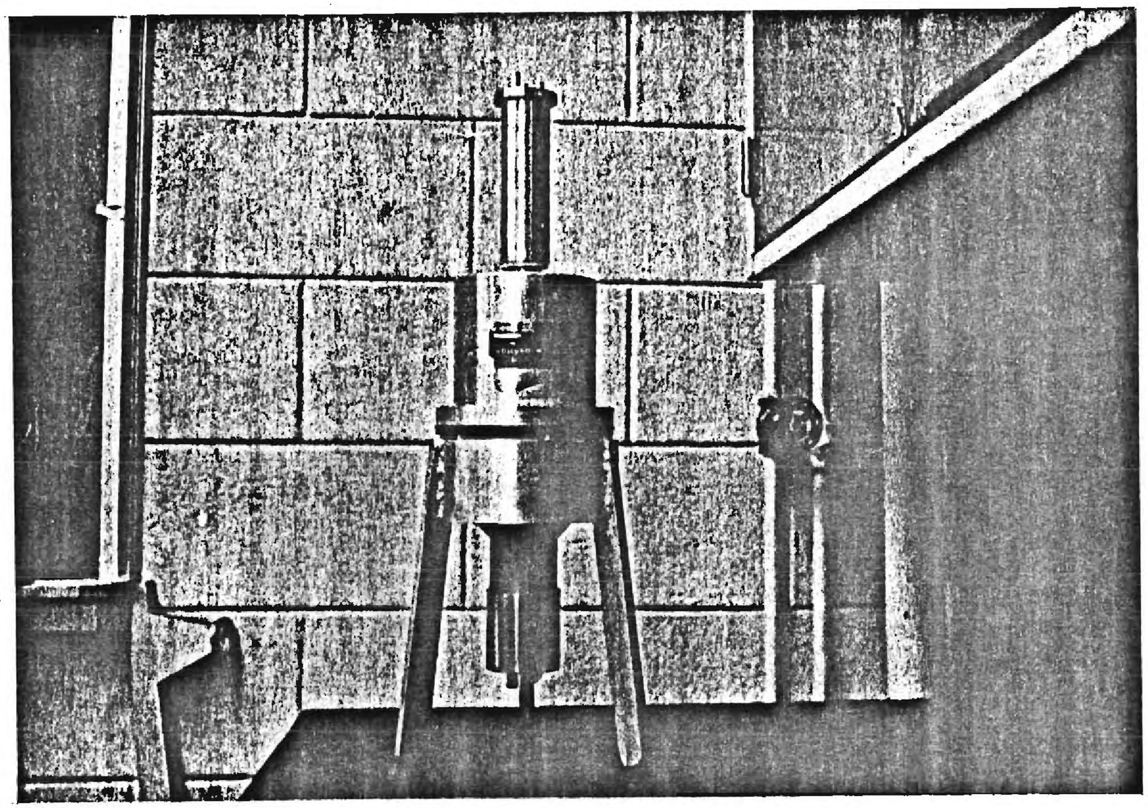

Figure 7-4 View of Detector Assembly

The source mounting is, of course, a critical part of the counting arrangement, and this arrangement worked well, especially considering that the source was removed and replaced many times with no problems.

The source was counted for one hour, removed, replaced, recounted, and so on for three or more times per day. Table 7-1 shows several examples of the resulting data; note that only one set of β counts fails the χ^2 test. (This test verifies the hypothesis that the observed counts are consistent with a normal distribution around the calculated mean, and a variance appropriate to that mean-Poisson distribution. A large value of χ^2 indicated that the data showed too much variation to be explained by the distribution of counts around the mean.) These numbers (and other days not included in the table) show a greatly improved reproducibility in the β-countrate.

For further characterization of the system, 1000-minute backgrounds were taken nearly every evening, for about six weeks. The results and analysis appear in Table 7-2. The two β-counts in parentheses were obtained on days when the photomultiplier had been exposed to light--the first day, and once when the Mylar had been changed. In both cases the system sat idle for several hours before the background was started, but the results of light exposure are obvious. (These two values were not used in the data analysis.)

The analysis of these background counts reveals an interesting fact: while both the β and γ backgrounds were not consistent with a constant value, the coincidence background was. In other words, the variance of the β and γ count values was larger than would be expected from the random fluctuation around a (constant) mean. The additional variability was due to a non-constant source of the background counts, most probably radon. Note also that these (β and γ) backgrounds were quite high, considering the size of the shield. (They were, however, consistent with values obtained earlier--the gamma count a bit lower because the γ-SCA window was slightly narrower.)

Error Analysis Study

The probable error in the net countrate was computed for a sample containing various amounts of activity, counted for various times, with different backgrounds, background count times, and detector (coincidence) efficiencies.

Table 7-1

SOURCE REPRODUCIBILITY DATA (WITHIN DAYS)

DATE		Count/60 Min COINC	β	γ
5/17		190	1065	15400
		208	1077	15547
		224	1122	15543
		222	1118	15650
		192	1089	15572
	$\bar{x}$ =	207.2	1094.2	15542.4
	s =	16.04	25.07	90.5
	χ^2 =	4.97	2.29	2.11
	$\chi^2_{4,.95}$ =	9.49		
5/19		182	995	15165
		198	1030	15383
		171	968	15331
		173	990	15387
	$\bar{x}$ =	181	995.75	15316.5
	s =	12.3	25.67	104.2
	χ^2 =	2.51	1.99	2.13
	$\chi^2_{3,.95}$ =	7.81		
5/21		131	863	15372
		145	949	15441
		159	962	15373
		139	927	15234
	$\bar{x}$ =	143.5	925.25	15355
	s =	11.8	43.9	86.89
	χ^2 =	2.92	6.26	1.48
	$\chi^2_{3,.95}$ =	7.81		
5/26		106	757	14918
		119	818	15189
		95	811	14980
		99	827	14982
		80	705	14881
	$\bar{x}$ =	99.8	783.6	14990
	s =	14.34	51.7	119.2
	χ^2 =	8.24	13.7	3.79
	$\chi^2_{4,.95}$ =	9.49		

Table 7-2

β - BACKGROUND DATA AND ANALYSIS

DATE	1000 - Minute Counts		
	COINC	β	γ
5/3	49	(21980)	252507
5/4	69	8290	255739
5/5	48	8648	256575
5/6	44	8959	244058
5/7	37	8820	243604
5/9	47	8907	241097
5/12	49	(12793)	246539
5/13	50	8386	246304
5/14	53	8603	247904
5/15	52	8785	245186
5/17	60	8790	244607
5/18	51	8776	242178
5/19	37	8594	243767
5/20	35	8662	243795
5/21	37	8601	244536
5/24	43	8967	243224
5/25	44	8597	245125
5/26	48	8465	241681
5/28	51	8774	252445
5/31	49	8843	253339
6/2	35	8735	249436
6/3	57	8767	242487
6/5	57	8615	244265
6/8	42	8921	246450
6/9	45	8896	246125
6/10	61	8806	246403

$N = 26$ $\nu_c = 25$ $\nu_\beta = 23$ $\nu_\gamma = 25$

$\chi^2_c = 37.15$ $\bar{x}_c = 48.08$ $s_c = 8.45$

$\chi^2_\beta = 81.94$ $\bar{x}_\beta = 8716.96$ $s_\beta = 176.23$

$\chi^2_\gamma = 1862$ $\bar{x}_\gamma = 246514$ $s_\gamma = 4285$

Average Count Rate: $(\bar{x}_i + 1/999.9)$

c: 0.049 cpm $(\pm\ 0.0070\ 1\sigma)\sqrt{\hat{c}/T}$

β: 8.719 cpm $(\pm\ 0.093\ 1\sigma)\sqrt{\hat{c}/T}$

γ: 246.54 cpm $(\pm\ 0.497\ 1\sigma)\sqrt{\hat{c}/T}$

Table 7-2 (Continued)

χ^2 values:

$\alpha = 0.95$, 1 tail	$\chi^2_c = 37.7$
	$\chi^2_\beta = 35.2$
	$\chi^2_\gamma = 37.7$
$\alpha = 0.95$, 2 tail	$\chi^2_c = 13.1, 40.6$
	$\chi^2_\beta = 11.7, 38.1$
	$\chi^2_\gamma = 13.1, 40.6$

λ Background Distribution Check

β-bkg

Range	Freq.	Normalized Range	Exp. Freq.
0 - 8600	5	$-\infty$, -0.6637	(0.2546)(24)=6.11
8600 - 8700	5	-0.6637 , -0.0962	(0.2056)(24)=4.93
8700 - 8800	6	-0.0962 , 0.4712	(0.2206)(24)=5.29
8800 - ∞	8	0.4712 , ∞	(0.3192)(24)=7.66

based on $\mu = 8716.96$
$\sigma = 176.23$

$\chi^2 = 0.312$
$\chi^2_{1,.95} = 3.8$

Accept H_o: distribution is normal (very weak test, 1 df)

γ-bkg

Range	Freq.	Normalized Range	Exp. Freq.
0 - 244k	8	$-\infty$, - .587	(0.2776)(26)=7.2
244k - 246k	6	-0.587 , -0.1199	(0.1746)(26)=4.5
246k - 248k	6	-0.1199 , 0.3468	(0.1846)(26)=4.8
248k - ∞	6	0.3468 , ∞	(0.3632)(26)=9.4

$\chi^2 = 2.1$
$\chi^2_{1,.95} = 3.8$

Accept distr. is normal

(Note that this is not the relative error in the activity, which must include the error in the efficiency value. The above ϵ_c had a relative error of ~ 15% at 1σ.) The expression used was

$$\text{R.E.} = \frac{\sqrt{(s+1)/T_s^2 + (B+1)/T_B^2}}{(s+1)/T_s - (B+1)/T_B}$$

where
s = sample gross counts
B = background counts
T_s = sample count time
T_B = background count time

A FORTRAN program was written to allow a large number of combinations of the parameter values to be used to calculate the relative error. One objective was to see what activity could be detected with a 5% relative error (at 1σ, in net cpm) with a two-hour count (a reasonable commercial time). For 10% efficiency and 0-10 cpm background this activity is 15 pCi. (A lower background would reduce this only slightly. For 5% relative error, one needs to count 5 pCi for six hours even with 0.005 cpm background.)

One way of presenting this information is graphically, as in Figures 3-1 and 3-2. These show (1) the relative error in net counts (cpm) associated with various amounts of I-131 activity, for various counting times, for a given background and efficiency; (2) the approximate activity required to obtain an ~ 5% relative error as a function of efficiency for two- and three-hour sample counts. Note that the background for Figure 3-1 is 0.05 cpm while that for Figure 3-2 is 0.10 cpm. This is an artifact of the way in which the computer runs were obtained and does not obviate comparisons between the two curves. (The computer data can be arranged in many other possible ways or can be easily re-run to cover parameter ranges of interest.)

Appendix B

REGULATORY ASPECTS OF ENVIRONMENTAL SURVEILLANCE PROGRAMS FOR NUCLEAR POWER PLANTS

W. C. Evans

I. INTRODUCTION

The optimization of environmental surveillance programs for nuclear power plants involves the consideration of a number of factors, among which are:

- what is to be measured
- where the measurement should be made
- with what frequency the measurement should be made
- with what accuracy and precision the measurement should be made
- how the data obtained are to be converted to a dose estimate

An important constraint on the optimization of these variables is that imposed by the regulatory agencies, in the sense that all the variables mentioned above may be to some extent defined by various regulatory positions and requirements. It is important, then, to examine both the general policy statements and the specific requirements and recommendations of the Environmental Protection Agency (EPA) and the Nuclear Regulatory Commission (NRC), as they pertain to environmental surveillance programs for nuclear power plants. This examination will follow the format given below:

- background information: discussion of EPA's proposed environmental radiation protection standards for the uranium fuel cycle
- background information: discussion of NRC's "as low as practicable" (ALAP) numerical guidance, as presented in Appendix I to 10CFR50
- a tabulation of regulatory positions relating to environmental surveillance
- conclusions and a summary of regulatory constraints on surveillance programs

II. ENVIRONMENTAL PROTECTION AGENCY--PROPOSED STANDARDS FOR ENVIRONMENTAL PROTECTION FOR NUCLEAR POWER FUEL CYCLE OPERATIONS (SUMMARY OF EPA'S DISCUSSION OF THE PROPOSED 40 CFR190; IN 40FR23420)

The government's "Reorganization Plan No. 3" of 1970 transferred to the EPA the broad guidance responsibilities of the former Federal Radiation Council. These responsibilities included the establishment of "generally applicable radiation standards" for the protection of the environment, which are to be implemented and enforced by the NRC. Thus, the proposed 40CFR190, which contains certain limits relevant to environmental surveillance, must be considered in an examination of regulatory constraints on such programs.

In brief, the proposed 40CFR190 places limits on the total potential radiological impact of the entire uranium fuel cycle on human populations. There are several noteworthy aspects of this rulemaking, which are summarized below:

- The EPA proposed rules are, in fact, radiation protection standards, as opposed to the NRC's "numerical guidance" presented in Appendix I to 10CFR50.
- The EPA rules consider the limitation of long-term doses to the human population, in addition to the limitation of short-term dose to the "maximum exposed individual."
- The EPA standards apply to the entire fuel cycle, including reprocessing and transportation.

The EPA dose limits for individuals assume the linear, no-threshold relationship between exposure and biological damage. The limits do, however, consider the costs of achieving very low exposure levels, and the standards "generally represent the lowest radiation levels at which the Agency has determined that the costs of control are justified by the reduction in health risk." The proposed limits on total quantities of certain long-lived isotopes which can be released in the fuel cycle are based on the generation of an offsetting quantity of electrical energy. That is, the radiological insult to the human population, present and future, due to the accumulation of long-lived materials in the environment must be balanced by a corresponding benefit which is taken to be the production of a certain amount of electrical energy. In the rulemaking process the specific limits will likely be considerably modified, but the concept is certainly a far-reaching and significant one.

The implementation of these proposed standards has been explicitly assigned to the NRC, and so the impact of these rules on environmental surveillance will be a function of how the NRC chooses to implement and enforce them. Since the EPA states that the monitoring and reporting requirements of the NRC, including Appendix I requirements, are acceptable for showing compliance with the proposed standards, the surveillance requirements are not changed by these rules. However, the limitation on the long-lived activity releases may require some further measurements either at the point of discharge or in the environment, or both. These limits will not become effective until 1983, at the earliest, and so do not pose an immediate problem, but they may become significant later.

III. NUCLEAR REGULATORY COMMISSION--RADIOACTIVE MATERIAL IN LIGHT-WATER-COOLED NUCLEAR POWER REACTOR EFFLUENTS (SUMMARY OF NRC'S DISCUSSION OF APPENDIX I TO 10CFR50; IN 40FR19439)

The NRC's guidance on effluents from light water reactors was recently approved for implementation. The EPA has stated that the NRC's requirements for evaluating and reporting radioactivity releases are acceptable for implementing EPA's proposed standards for environmental protection. Thus it is worth examining the NRC comments that accompanied the publication of the Appendix I rules in the Federal Register to gain some perspective on the limits and their rationale.

The first point worth noting is that the "Appendix I guides as . . . adopted by the Commission are not radiation protection standards." They are, rather, a "quantitative expression of the meaning of the requirement that radioactive material in effluents released to unrestricted areas from light-water-cooled nuclear power reactors be kept as low as practicable." From the point of view of compliance, including the appropriate surveillance, the point is academic--one must still show that the limits given are met.

Another interesting point is in the NRC's discussion of the changes made between the proposed and adopted limits, which of course took several years. In some instances limits were raised because it had been shown that some limits were not practicable or had no particular meaning. The increases, however, were only by a factor of three (5 mrem to 15 mrem) and thus will not appreciably alter any surveillance requirements for sensitivity that may be inferred from a dose limit.

More directly to the point, the NRC states that "the Commission has expanded the surveillance and monitoring program beyond current requirements for licensees to report on the quantities of the principal radionuclides released to unrestricted areas." The expansion apparently consists of a requirement to "evaluate the relationship between quantities of radioactive material released in effluents and resultant radiation doses to individuals from principal pathways of exposure." (This is in the text of Appendix I, not in the commentary.) The idea apparently is to improve the models used for calculating the doses to individuals, and the NRC states that there is an economic incentive for this improvement, due to "needless overdesign for conservatism." It seems, then, that there is a new, binding requirement to correlate measurements at the discharge point to those in the plant environs. The NRC recognizes, however, that "measurements of environmental exposures and quantities of radioactive materials in the environs are complicated by the very low concentrations that are encountered, compared to background, and by the fact that there are a number of variables in both time and space that affect concentration. Thus, the correlation of the best measurements with the best calculations is tedious and difficult." They go on to say that since one must make calculations anyway for Appendix I purposes, they do want these correlations made. (This would imply a direct extension of the EPRI study to effluent monitoring.)

IV. TABULATION OF REGULATORY DOCUMENTS PERTAINING TO ENVIRONMENTAL SURVEILLANCE FOR NUCLEAR POWER PLANTS

(1) 10CFR20.105

a. Requirements: 20.105(a), direct radiation in unrestricted area, less than 0.5 rem whole body in one year; 20.105(b)(1), direct radiation in unrestricted area, less than 2 mrem in one hour; 20.105(b)(2), direct radiation in unrestricted area, less than 100 mrem in seven consecutive days.

b. Purpose: limit dose to public

c. Sensitivity/Method: N/A

d. Cross-reference: N/A

e. Relevance: implies site-boundary dose/dose-rate measurement.

(2) 10CFR20.106

a. Requirements: if the daily intake by the exposed population is in excess of that intake resulting from continuous exposure to one-third the appropriate value in Appendix B, Table II (yearly average) NRC will limit quantities discharged (air and water).

b. Purpose: limit dose to public

c. Sensitivity/Method: N/A

d. Cross-references: 10CFR50.36a, Regulatory Guides 4.1, 4.3, 4.5, 4.6

e. Relevance: requires an estimate of population uptake.

(3) 10CFR20.201

a. Requirements: explicit requirement for surveys (measurements) to show compliance with regulations in Part 20.

b. Purpose: to provide a definite requirement for proof-of-compliance measurements

c. Sensitivity/Method: N/A

d. Cross-references: Regulatory Guides 4.1, 4.3, 4.5, 4.6

e. Relevance: legal basis for monitoring and surveillance program requirements.

(4) 10CFR50.36a

a. Requirements: semiannual report on quantities of "each of the principal radionuclides" released

b. Purpose: "to estimate maximum potential annual radiation doses to the public resulting from effluent releases"

c. Sensitivity/Method: N/A

d. Cross-references: 10CFR20.106, Appendix I to 10CFR50, Regulatory Guides 1.42, 4.3, 4.6

e. Relevance: implies effluent, as opposed to environmental, measurements, but is used as justification for the latter.

(5) 10CFR50, Appendix A, General Design Criterion 64

a. Requirements: "Means shall be provided for monitoring . . . the plant environs for radioactivity that may be released . . . ."

b. Purpose: to assess the dose to the public, especially for accident situations, in which the release may not occur in a monitored path

c. Sensitivity/Method: N/A

d. Cross-reference: Regulatory Guides 4.1, 4.3, 4.6

e. Relevance: perhaps the most explicit requirement for environmental surveillance, but with no constraints on the program.

(6) 10CFR50, Appendix E (Emergency Plans)

a. Requirements: paragraph IV,C "Means for determining the magnitude of the release of radioactive materials . . . ."

b. Purpose: ". . . protect health and safety . . ."

c. Sensitivity/Method: N/A

d. Cross-references: N/A

e. Relevance: implies some means of fast-responding assessment of release in the environment--could be a significant factor.

(7) 10CFR50, Appendix I, ALAP for LWR Effluents

a. Requirements: Section II places limits on maximum annual dose to an individual exposed to LWR effluents; Section IV,B requires "an appropriate surveillance and monitoring program" that will provide data on the quantities of material released and "measurable levels of radiation and radioactive materials in the environment."

b. Purpose: the monitoring program is to "evaluate the relationship between quantities of radioactive material released in effluents and resultant radiation doses to individuals from principal pathways of exposure."

c. Sensitivity/Methods: implies sufficient sensitivity to make the required correlations at some meaningful statistical confidence level.

d. Cross-references: 10CFR50.36a

e. Relevance: inasmuch as the environmental program is capable of providing dose estimates, it should have sensitivities defined by the dose limits given in Appendix I; thus this document provides a constraint on these programs. However, a case can be made for the idea that the dose-sensitivity relationship is far more relevant to effluent monitoring (Regulatory Guide 1.21) than to environmental surveillance. In any case, the correlation requirement certainly imposes a new consideration on the design of operational environmental monitoring programs.

(8) Regulatory Guide 1.42, ALAP for Radioiodine Releases from LWR's

a. Requirements: effectively the same as Appendix I

b. Purpose: to present "acceptable" models for iodine dose calculations

c. Sensitivity/Methods: the methods based on Slade are used.

d. Cross-references: 10CFR50, Appendix I, 10CFR50.36a, 10CFR-20.1(c) (ALAP statement)

e. Relevance: gives calculational models that are relevant for dose calculations and correlation estimates.

(9) Regulatory Guide 4.1, Environmental Monitoring Programs for Nuclear Power Plants

a. Requirements: recommends a number of sampling criteria that are of an "acceptable" nature to the regulatory staff.

b. Purpose: to outline general criteria for an environmental surveillance program from which "suitable information (regarding) levels of radiation and radioactivity in the environs of each plant can be developed."

c. Sensitivity/Methods: "Every reasonable effort should be made to achieve detection capabilities that will detect radiation levels or radioactivity concentrations in pathways that could result in radiation doses corresponding to a few percent of the Federal Radiation Council's radiation protection guides (i.e., a few percent of 170 mrem/yr for whole body dose to a suitable sample of the population)."

d. Cross-references: 10CFR50, Appendix A, GDC 64, 10CFR20.106(3), 10CFR20.201

e. Relevance: a valuable guide for design of environmental surveillance programs.

(10) Regulatory Guide 4.3, Measurement of I-131 in Milk

a. Recommendations: an acceptable method for environmental levels of I-131 in milk is given.

b. Purpose: to provide guidance on an acceptable analytical method for I-131 in milk

c. Sensitivity/Method: ion exchange, extraction, precipitation, beta counting; 0.25 pCi/ℓ for 4 liters counted for 1000 min with a background of 0.5 - 1 cpm

d. Cross-references: 10CFR50 GDC 64, 10CFR50.36a, 10CFR20.106, 10CFR20.201, 10CFR20.1, 10CFR50, Appendix I (by inference)

e. Relevance: an explicit method for I-131 in milk is given that is acceptable to the NRC staff.

(11) Regulatory Guide 4.5, Soil Sampling and Analysis for Plutonium

a. Recommendations: explicit methods of soil sampling and analysis are given.

b. Purpose: to give an acceptable method for plutonium sampling and analysis in soil

c. Sensitivity/Method: the HASL-300 methodology for soil sampling and preparation is given. The plutonium analysis is from a LASL method; the main features are an acid extraction, ion exchange, electro-deposition and alpha spectrometric counting. No sensitivity is quoted.

d. Cross-references: 10CFR20.106, 10CFR20.201, 10CFR20.1

e. Relevance: the main usefulness of this guide is in its exposition of acceptable soil sampling techniques, regardless of the analysis.

(12) Regulatory Guide 4.6, Measurement of Sr-89-90 in the Environment

a. Recommendations: radioanalytical methods are given for Sr-89 and Sr-90 in the environment.

b. Purpose: to provide an acceptable analytical method for these isotopes

c. Sensitivity/Method: the HASL-300 method is used. No sensitivity is quoted.

d. Cross-references: 10CFR50, GDC 64, 10CFR50.36a(a)(2), 10CFR20.106(e), 10CFR20.201, 10CFR20.1

e. Relevance: acceptable methods are given for Sr-89 and Sr-90 (given that it has been determined that the analysis is at all necessary).

(13) Regulatory Guide 4.2, Environmental Reports for Nuclear Power Stations

a. Requirements: a number of requirements are given, in sections 5.2, most of chapter 6. Section 6.4 requires "6 to 12 months" of preoperational environmental surveillance data.

b. Purpose: to provide guidance on the content of environmental reports for nuclear power stations

c. Sensitivity/Method: N/A

d. Cross-references: 10CFR51--the regulation embodying NRC's implementation of the national environmental policy act

e. Relevance: many of the dose calculations requested here will need to be verified per Section IV,C of Appendix I by the environmental surveillance program. Some other useful information is in section 6.1.5.

(14) Regulatory Guide 4.8, Environmental Technical Specifications for Nuclear Power Plants

o This guide is not yet available, but it will no doubt be relevant; issued in draft form December 1975.

(15) Regulatory Guide 1.70 Series, Standard Format for SAR's

a. Requirements: in section 11.6 the environmental program must be described in detail.

b. Purpose: to evaluate the capability of the program to "determine, in conjunction with effluent monitoring, estimates of individual and population exposure beyond the site boundary, at the design and accident levels of radiation and radioactive effluents."

c. Sensitivity/Methods: must be described in detail

d. Cross-references: N/A

e. Relevance: the information required in section 11.6 includes expected background; critical pathways, sampling media, locations, and frequency; analytical sensitivity; data analysis and presentation; program statistical sensitivity. Note that the Standard Review Plan for section 11.6 would contain further information. This material is useful for determining what NRC is looking for in environmental programs.

V. SUMMARY AND CONCLUSIONS

The explicit requirements for environmental surveillance for any given plant will be contained in its technical specifications, and thus the final determination of what is to be measured, how often, to what sensitivity, etc. will be made by NRC on an essentially case-to-case basis. Thus it is difficult to pin down exactly, from the above regulations, just what will be required. However, it is clear that environmental measurements must be made (GDC 64) and they must at least provide data for correlation with effluent monitoring results (Appendix I, Section IV). One interesting point is that all the Regulatory Guides invariably begin with a quotation of a series of regulations, as if those regulations made specific reference to the particular topic of the Regulatory Guide. In many cases the connection between the legal requirements of the regulation and the "guidance" of the Regulatory Guide is not at all clear. For example, Regulatory Guide 4.6 (Sr-89-90) quotes 10CFR50.36a(a)(2), 20.106, 20.201, etc., when none of those regulations says a word about strontium. In a sense, these guides are acting as an extension of the regulations, rather than providing guidance on ways to meet the existing requirements.

In any case, the regulatory documents that conspire to place bounds (including existence) on environmental surveillance programs are as outlined below:

- GDC 64--there must be a program
- Appendix I--an "appropriate" program that provides "data on measurable levels of radiation and radioactive materials in the environment
- Regulatory Guide 4.1--general criteria relevant to an acceptable program
- Regulatory Guide 4.2--chapter 6, with criteria that NRC clearly consider to be important, but without the specifics that would constrain a program
- Regulatory Guides 4.3, 4.5, 4.6--acceptable analytical methods, given the need to make that measurement.